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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

INCLUDING THE

PROGRAMME OF THE

1959 SUMMER MEETING IN THE WEST

AT

HONOLULU, HAWAII

August 27, 28, and 29

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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

1959 Summer Meeting in the West, University of Hawaii, Honolulu, Hawaii, August 27–29, 1959

WITH an acute sense of timing, The American Physical Society is holding its regular **meeting in the West** at the University of Hawaii in Honolulu just as Hawaii is to become the 50th state in the Union. In fact, the deadline for this issue of the Bulletin comes just a few days after the Hawaiian election validating the accession. The meeting will be held on the campus of the university on Thursday, Friday, and Saturday, August 27, 28, and 29. The sessions will be held in Crawford Hall and George Hall, which are neighboring buildings.

Although the **hotel information** given in the Preliminary Announcement will be repeated here, it probably will be of little use at the late date this Bulletin will be received. You will do well to consult a reliable travel agent for formal reservations. The Princess Kaiulani Hotel in Waikiki has set aside a block of rooms for members of the Society and has promised to find equivalent rooms in other hotels in Waikiki of the same chain for overflow. The rates at the Kaiulani are $12 for a single and $14 for a double. We list some additional hotels in the Waikiki area to give some idea of the scale of prices: Moana Hotel, $12 single, $14 double; Islander Hotel, $5, $6, $8 single, $7.50, $8.50, $9.50 double; Edgewater-Reef Hotel, $7.50, $8.50, $9.50 single, $10, $12, $14 double; Waikiki Biltmore Hotel, $8, $9, $10, $11 single; $12, $14, $16, $18 double; Hawaiian Village, $10, $12, $14, $16 single, $12, $14, $18 double. There are more expensive and more luxurious hotels than these, but we assume that those people who plan to use them need no advice on this account. Although the Waikiki hotels are relatively close to the campus, bus transportation is inconvenient, since it is necessary to make two transfers, using buses numbers 2, 4, and 5. Taxis cost only about $1.20 between Waikiki and the university, with no charge for additional passengers.

Air **transportation from San Francisco and Los Angeles** is via Pan American and United Air Lines. In addition, there is Northwest Orient Airlines from Seattle and Quantas and Japan Air Lines from Vancouver. Economy flights are offered by Transocean Airlines and U. S. Overseas Airlines. Ship schedules are less flexible, and there are only two ships leaving San Francisco that are reasonable from the viewpoint of the meeting; one arrives approximately a week before and the other arrives, unfortunately, on the morning of the first day of the meeting. Space is probably no longer available on these ships. Lunch will be no problem, since the facilities will be available on the campus.

Registration and the usual information will be at the desk in Gartley Hall which houses the Physics Department. The registration fee will be $1.

Tickets for the banquet of the Society will be sold at the registration desk and the price will be $4 per person. The dinner will be at 8:00 P.M. at the Princess Kaiulani Hotel, and there will be a cocktail party for the members of the Society, generously sponsored by the Hawaii Electric Company, starting at about 6:30 P.M., also at the Princess Kaiulani Hotel. Our principal speaker will be Chancellor Glenn T. Seaborg of the University of California at Berkeley, and the Society will be welcomed at the banquet by President Lawrence H. Snyder of the University of Hawaii. President Snyder is no stranger to the Society, having already been a banquet speaker at the Physical Society meeting in Norman, Oklahoma, in 1957.

The program consists of **131 contributed papers and 54 invited papers.** This is now the second time that it has been necessary to have four sessions in parallel at a summer meeting, and there are several undesirable conflicts in the program. The program was arranged with the help of Professors L. Wilets,

R. L. Thornton, E. L. Hahn, K. M. Watson, and Dr. F. S. Johnson.

There are so many things to do in Hawaii, and so little time for the average visitor to do them all, that the Local Committee is making no special arrangements for the members of the Society and their families. If a special program is arranged, information will be obtainable at the registration desk. Professor Kenichi Watanabe is Chairman of the Physics Department and Chairman of the Committee on Local Arrangements, and if any questions as to physical arrangements arise, they should be addressed directly to him in care of the Physics Department at the University of Hawaii.

Post-deadline papers of sufficient importance to warrant their inclusion in a special supplementary program will be considered by the Local Secretary if the abstracts are received no later than Friday, August 21, at the Office of the Local Secretary for the Pacific Coast (see address below). These papers will be presented following sessions that will be designated on a blackboard near the registration desk in Gartley Hall.

Errata pertaining to abstracts in this issue will be published in a later issue of this Bulletin if received not later than Tuesday, September 8, by Miss Ruth Bryans, American Institute of Physics, 335 East 45 Street, New York 17, New York. Do not send in the abstract with erasures and corrections. Write out your corrections in the form "Instead of . . . read . . ."; add nothing.

W. A. NIERENBERG,
Local Secretary for the Pacific Coast
Department of Physics
University of California
Berkeley 4, California

EPITOME* OF THE 1959 SUMMER MEETING IN THE WEST AT THE UNIVERSITY OF HAWAII

(Personal names are those of invited speakers.)

Thursday Morning

9:45 A. Atomic physics I; Neynaber, Branscomb, Stebbings, Bederson, Meyerott, Phelps. 103.

9:45 B. Low-energy nuclear physics I; Boehm, Schmidt, DuMond, Diamond, Asaro, Fairhall. 105.

10:00 C. Magnetohydrodynamics; Linlor. 209.

10:30 D. Resonance physics. 226.

Thursday Afternoon

1:45 E. Atomic physics II; Thomas, Borowitz, Mittleman, Karzas, Peterson. 103.

2:00 F. Low-energy nuclear physics II; Farwell, Inglis, Talmi, Griffiths, Manning. 105.

1:45 G. High-energy nuclear physics; Bradner. 209.

Friday Morning

9:30 H. Radio-frequency spectroscopy I; Bloom, Oppenheim, Norberg, Bender, Jaynes, Birnbaum, Anderson. 103.

9:45 I. High-energy nuclear physics I; Pais, Miller, Muller, Glaser, O'Neill. 105.

10:00 J. Low-energy nuclear physics. 209.

9:00 K. Satellites and other topics; Kaplan. 226.

Friday Afternoon

1:45 L. Radio-frequency spectroscopy II; Anderson, Novick, Portis, Kikuchi, Franken. 103.

1:45 M. High-energy nuclear physics II; Walker, Mozley, Mandelstam, Ypsilantis, Telegdi. 105.

2:30 N. Solid-state physics. 209.

2:00 O. Magnetohydrodynamics. 226.

Friday Evening

8:00 Banquet of the American Physical Society; Seaborg. Princess Kaiulani Hotel.

Saturday Morning

9:30 P. Space physics; Zirker, Helliwell, Northrop, Dessler, Hess. 105.

9:30 Q. Low-energy nuclear physics. 103.

9:30 R. High-energy nuclear physics; Korff. 209.

Saturday Afternoon

1:30 S. Solid-state physics. 105.

1:30 T. Low-energy nuclear physics. 103.

1:30 U. Theoretical physics. 209.

* Rooms 103, 105, and 209 are all in Crawford Hall. Room 226 is in George Hall.

PROGRAMME

THURSDAY MORNING AT 9:45

Crawford 103

(K. M. WATSON presiding)

Invited Papers on Atomic Physics I

A1. Molecular Beam Studies at Convair. R. H. NEYNABER, *Convair.* (10 min.)

A2. The Electron-Negative Ion Ratio in the Lower Ionosphere. L. M. BRANSCOMB, *National Bureau of Standards.* (25 min.)

A3. Measurement of Atomic Cross Sections Using Modulated Atom Beam Techniques. R. F. STEBBINGS, *General Atomic.* (25 min.)

A4. Low-Energy Electron-Atom Scattering Studies by an Atom Recoil Method. B. BEDERSON, *New York University.* (25 min.)

A5. Phenomena Associated with Slowing Down of High-Energy Particles in Air. R. E. MEYEROTT, *Lockheed Aircraft Corporation.* (25 min.)

A6. Laboratory Studies of Electron Attachment in Oxygen and of Elastic and Inelastic Scattering in Nitrogen. A. V. PHELPS, *Westinghouse Corporation.* (25 min.)

THURSDAY MORNING AT 9:45

Crawford 105

(J. H. D. JENSEN presiding)

Invited Papers on Low-Energy Nuclear Physics I

B1. Circular Polarization Correlation Studies of γ Rays in β Decay. FELIX H. BOEHM, *California Institute of Technology.* (20 min.)

B2. Positron Polarization in Fermi Transitions. F. H. SCHMIDT, *University of Washington.* (20 min.)

B3. High-Precision Instrumentation for Low-Energy Nuclear Spectroscopy. J. W. M. DUMOND, *California Institute of Technology.* (20 min.)

B4. Coulomb Excitation with Heavy Ions. R. M. DIAMOND, *University of California, Berkeley.* (20 min.)

B5. Anomalous Electric Dipole Conversion Coefficients. F. ASARO, *University of California, Berkeley.* (20 min.)

B6. Fission Studies of the Medium-Heavy Elements. A. W. FAIRHALL, *University of Washington.* (20 min.)

THURSDAY MORNING AT 10:00

Crawford 209

(H. C. CORBEN presiding)

Magnetohydrodynamics

Invited Paper

C1. Plasma-Target Fusion Machine. W. I. LINLOR, *Hughes Aircraft Company.* (30 min.)

Contributed Papers

C2. The Berkeley Spiral-Ridged Cyclotron. ELMER L. KELLY, *University of California, Berkeley.*—The new 88-in. cyclotron under construction at Berkeley will be discussed. This accelerator is designed to produce a large external current of a variety of ions with continuously variable energy up to a maximum of 30 Mev/nucleon. This high energy at moderate dee voltage will be achieved by increasing the average magnetic field quadratically with radius to adjust for the relativistic

mass increase of the ions. The ion defocusing normally caused by the radially increasing field is prevented by the strong focusing effects of azimuthal variations. The variation of energy is made possible by pole face windings and an rf system whose frequency can be varied over a range of three to one by means of movable panels. Adequate beam extraction is expected from a conventional electrostatic deflector. This machine will be used primarily for nuclear chemistry. By adding a frequency modulation unit to the rf system, this cyclotron will accelerate protons to an energy of 115 Mev.

C3. Continuous Beam Extraction Methods for FFAG Accelerators.* L. W. JONES AND K. M. TERWILLIGER, *University of Michigan and Midwestern Universities Research Association.*—To fully utilize the long duty factor potentially available with FFAG accelerators it is desirable to be able to extract a circulating beam slowly. The Piccioni-Wright system[1] as applied to pulsed field accelerators is not applicable to fixed field machines. One modification for FFAG accelerators makes use of the pulsating nature of the envelope of the betatron oscillations. An energy loss foil is located at an azimuth where radial oscillations have smallest amplitude. Where the envelope is a maximum, and after an integral number of betatron oscillations, the outward induced oscillation will be greater than the inward orbit shift, resulting in a net increase in the radius of the particle and allowing insertion of a septum. Another system applicable to all circular accelerators uses a field gradient perturbation,[2] producing an enhanced separation of particle equilibrium orbits at the energy loss foil, and superposition of these orbits at the extractor. Then a given energy loss in the foil produces an increased betatron oscillation and a net radial separation from previous orbits at the system.

* Supported by the U. S. Atomic Energy Commission.
[1] B. T. Wright, Rev. Sci. Instr. **25**, 429 (1954); Piccioni, Clark, Cool, Friedlander, and Kassner, Rev. Sci. Instr. **26**, 232 (1955).
[2] K. M. Terwilliger, Bull. Am. Phys. Soc. Ser. II, **4**, 269 (1959).

C4. Formal Connection of Plasma Confining Field and Accelerator Phase Space Topologies.* D. W. KERST, *General Atomic.*†—Equations of a line of force $dx/dz=B_x/B_z$ and $dy/dz=B_y/B_z$ and focusing equations for accelerator phase space $dp/dt\sim B_y$ and $dx/dt\sim p$ show that for B_z constant in space the z and y are formally equivalent to t and p for particle orbits in a focusing field with the same B_z and B_y but with no B_x provided $B_z\sim y$—the case for linear focusing forces. Thus particle paths in phase space are similar to line of force paths in coordinate space with an appropriate B_x. Variation of B_y with z spoils the analogy since p does not vary like B_y. Thus the familiar quadrupole case,[1] $l=2$, is altered. Nonlinearly changing fields are equivalent to the hamiltonian not being quadratic in p but methods similar to transformation methods for accelerators can be used to discuss stability and the influence of field errors on the confinement of lines of force.

* This work was done under a contract between General Atomic and the Texas Atomic Energy Research Foundation.
† John Jay Hopkins Laboratory for Pure and Applied Science, General Atomic Division of General Dynamics Corporation, San Diego, California.
[1] L. Spitzer, Jr., Phys. Fluids **1**, 257 (1958).

C5. Propagation of Alfvèn Waves in a Compressible Cylindrical Plasma.* R. L. MOORE, *Richard L. Moore Consultants.*—Wave velocities of greater than Alfvèn speed have been reported in recent experiments,[1] where waves were propagated along an axial magnetic field. The increase in velocity possibly is due to the speed of propagation of homologous pulsations of a cylindrical plasma along the axis similar to the transverse oscillations previously described.[2] These waves are similar to those postulated by Heaviside[3] for compressional magnetic waves, although the lack of experimental evidence caused him to doubt their existence. The present hydrodynamic theory† results in a nonlinear wave equation in the velocity function, $v=V/z$, as follows:

$$\frac{\partial^2 v}{\partial t^2}+(3+\gamma)v\frac{\partial v}{\partial t}+v^2(\gamma+1)+v\left\{\frac{H_0^2}{4\pi\rho z_0}\left(\frac{\gamma+1}{z}-\frac{1}{z_0}\right)+\frac{H_1^2\gamma}{4\pi\rho z z_0}\right\}+\dot{H}_1H_1/(2\pi\rho z_0)=0.$$

Here H_0 is the axial magnetic field and H_1 is the pulsed field.

* Work supported by Norair Division, Northrop Corporation.
† Based on equations due to Eddington as referenced in 2.
[1] Allen, Baker, Pyle, and Wilcox, Phys. Rev. Letters **2**, 383 (1959).
[2] R. L. Moore, Bull. Am. Phys. Soc. Ser. II, **4**, 247 (1959).
[3] O. Heaviside, *Electromagnetic Theory* (New York, 1950), p. 242.

C6. Steady Two-Dimensional Flow with a Transverse Magnetic Field. MORTON MITCHNER, *Lockheed Missiles and Space Division.*—Equations are developed for the steady, two-dimensional, isentropic and irrotational flow of a perfect electrically conducting fluid in a transverse magnetic field. For very strong magnetic fields the magnetohydrodynamic equations are identical to the corresponding hydrodynamic equations specialized to a gas with a ratio of specific heats equal to two and with the sound velocity replaced by the total disturbance velocity. The effect of the magnetic field on the Bernoulli equation is examined, and the characteristic curves in the hodograph plane calculated for the case of supersonic flow. It is shown that a magnetic field causes a more rapid expansion for flow around a convex curved wall, and causes the shock produced in flow around a concave curved wall to move upstream. For comparable Mach numbers these effects are relatively small, even for very strong fields.

C7. Plasma Oscillations in a Static Magnetic Field. HOWARD H. C. CHANG, *Hughes Aircraft Company.*—The small amplitude oscillations of a plasma in a static magnetic field, $\vec{H}_0$, is discussed. The plasma is assumed to be a perfectly conducting, nonviscous fluid composed of two perfect gases, electronic and ionic. For each component we write the linearized hydrodynamic equation of motion, the equation of continuity and Maxwell's equations. All small perturbations are assumed to vary as $f(\vec{k},\vec{r},\omega,t)=\exp[i(\vec{k}\cdot\vec{r}-\omega t)]$, where $\vec{k}$ is the wave vector, $\vec{r}$ the position vector, and ω is the wave frequency. With $\vec{k}$, $\vec{H}_0$, $\vec{v}$ (the macroscopic velocity of the plasma), $\vec{u}$ (the relative velocity of the ions with respect to the electrons), r_0 (the ratio of the electronic to the ionic mass), ω_p (the plasma frequency), ω_{c_e} (the electron cyclotron frequency), c (the velocity of light), $a=c/(\omega_p\omega_{c_e})^{\frac{1}{2}}$ (a characteristic length) and $R=1+\omega_p^2/(c^2k^2)$ as parameters a sixth degree dispersion relation in ω^2 is obtained. The dispersion relation is solved for the high-frequency case when $ka\gg1$ and $ka\ll1$, and for the low-frequency case when $Rr_0\gg1$ and $Rr_0\ll1$. The physical significance of all cases is discussed especially as regards the motion of the particles and the propagation of waves in the plasma. Alfvén's transverse hydromagnetic waves and the magnetoacoustic waves are recovered as special cases.

C8. Moment Equations and Boundary Conditions for Magnetogasdynamics.* H. T. YANG, *University of Southern California.*—Based on the work of Burgers and particularly of Kolodner, moment equations are obtained (from the Boltzmann equation) for a conducting gas in electric and magnetic fields. There are always the conservation equations of mass, momentum, and energy with the quantities of stress and heat flux remaining to be specified. By assuming slight ionization and the Grad distribution function, we obtain the stress and the heat flux equations. The associated boundary conditions are developed by taking this distribution function and applying the conservation laws near the wall. These

moment equations and boundary conditions together with Maxwell's electrodynamic equations and boundary conditions form a determinate system to describe the behavior of a conducting rarefied gas in electric and magnetic fields. This system includes both the Grad thirteen-moment equations for rarefied gases and the usual continuum magnetogasdynamics as limiting cases.

* Supported by the Office of Scientific Research.

THURSDAY MORNING AT 10:30

George 226

(D. NAGLE presiding)

Resonance Physics

D1. Statistical Properties of Atomic Spectra.* N. ROSENZWEIG AND C. E. PORTER, *Argonne National Laboratory and University of Minnesota.*—Examination of the energy level schemes[1] of some complex atoms reveals that the statistical properties which have recently been discussed for nuclear spectra[2,3] are also present in atomic spectra. For example, in neutral Os the spacings between the odd parity levels of a fixed angular momentum J have a distribution fairly close to Wigner's distribution $\frac{1}{2}\pi x \exp(-\frac{1}{4}\pi x^2)$. If the levels are not separated according to J, the repulsion is reduced in accordance with theoretical expectations. In cases where the spin-orbit coupling is small (e.g., Fe I), the same statistical laws hold for the spacing between the "centers of gravities" of multiplets having the same parity and SL values. In these cases the matrices of the electrostatic interaction in the SL scheme seem to have the statistical properties which are known[2,3] to lead to the repulsion of levels.[4]

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] "Atomic Energy Levels as Derived from Optical Spectra," compiled by C. E. Moore; Natl. Bur. Standards Circ. No. 467.
[2] S. Blumberg and C. E. Porter, Phys. Rev. 110, 786 (1958).
[3] N. Rosenzweig, Phys. Rev. Letters 1, 101 (1958).
[4] For similar evidence in the nuclear case see C. E. Porter and N. Rosenzweig, Bull. Am. Phys. Soc. Ser. II, 4, 319 (1959).

D2. Spin Wave Resonance in Thin Permalloy Films with H_0 Parallel to the Film. C. F. KOOI AND R. W. MOSS, *Lockheed Research Laboratories.*—Standing spin wave resonances were observed by Seavey and Tannenwald[1] in thin permalloy films when the static magnetic field, H_0, was perpendicular to the film. We have observed resonances, with H_0 in the plane of the film, which we believe to be standing spin wave resonances. We also observed standing spin waves with H_0 perpendicular to the film. Values of the exchange constant A will be given for both the perpendicular case and the parallel case. These measurements were made at a frequency of 9350 mc/sec. The film had a $g=2.02$, $4\pi M_s=9413$, and a thickness of 2395 A.[2]

[1] M. H. Seavey, Jr., and P. E. Tannenwald, Phys. Rev. Letters 1, 168 (1958).
[2] The film was supplied by R. L. Conger, NOL, Corona.

D3. Nuclear Spins of I^{126}, I^{133}, and I^{135}.* HUGH L. GARVIN AND EDGAR LIPWORTH, *University of California, Berkeley.*—The nuclear spins of some radioactive iodine isotopes have been measured by an atomic beam experiment, and the results are given in Table I. The apparatus used has been described elsewhere.[1] Iodine-126 was produced by the (p,n) reaction on tellurium metal. Brookhaven National Laboratory provided I^{133} as a reactor fission product. Iodine-135 was produced in the fission of U^{235} by deuteron bombardment in the Berkeley 60-in. cyclotron. The radioactive beam was collected upon silver-coated buttons which were subsequently counted in continuous-flow proportional counters. Isotope identification was made by decay half-life and gamma-ray spectrum analysis. Both "flop-in" resonances in the upper hyperfine states of the $^2P_{\frac{1}{2}}$ atomic ground state were observed at each magnetic field.

TABLE I.

Isotope	Half-life	Spin	Magnetic field (gauss)
I^{126}	13.3 day	2	0.71, 1.42, 6.92
I^{133}	21 hr	7/2	2.82, 6.92, 13.42
I^{135}	6.7 hr	7/2	2.82, 6.92, 10.87

* This research was performed under the auspices of the U. S. Atomic Energy Commission.
[1] Garvin, Green, and Lipworth, Phys. Rev. 111, 534 (1958).

D4. Nuclear Spin of 2.3-hr Iodine-132.* EDGAR LIPWORTH, HUGH L. GARVIN, AND W. A. NIERENBERG, *University of California, Berkeley, and Miller Institute for Basic Research in Science.*—The nuclear spin of 2.3-hr iodine-132 has been measured by means of an atomic-beam magnetic-resonance experiment and found to have the value 4. The apparatus used for this measurement has been described elsewhere.[1] Iodine-132 is conveniently obtained by a milking process from 77-hr tellurium-132 in an iodine generator provided by the Brookhaven National Laboratory.[2] A generator initially charged with 108 millicuries of I^{132} provided a sufficient quantity of active material to observe the "flop-in" resonances of the $F=11/2$ and $F=9/2$ hyperfine states of the $^2P_{\frac{1}{2}}$ atomic ground state at magnetic field values of 1.42, 2.82, 6.92, and 13.42 gauss. The I^{132} beam was detected by collection upon silver-coated buttons which were subsequently counted in continuous-flow proportional counters. Decay half-life of both the principal sample and several resonance-maxima samples were used to reaffirm identification of the isotope. The observed value of 4 for the nuclear spin of I^{132} is consistent with the single-particle shell model of the nucleus.[3]

* Work done under the auspices of the U. S. Atomic Energy Commission, and the Air Force Office of Scientific Research.
[1] Garvin, Green, and Lipworth, Phys. Rev. 111, 534 (1958).
[2] Stang, Tucker, Banks, Doering, and Mills, Nucleonics 12, No. 8, 22–24 (1954).
[3] M. G. Mayer and J. H. D. Jensen, *Elementary Theory of Nuclear Shell Structure* (John Wiley & Sons, Inc., New York, 1955), pp. 194–196.

D5. Hyperfine Structure Separation and Magnetic Moment of (3.3 hr) Cu^{61}.* BARBARA DODSWORTH, V. J. EHLERS, W. B. EWBANK, F. R. PETERSEN, AND H. A. SHUGART, *University of California and Lawrence Radiation Laboratory.*—The hyperfine structure splitting of 3.3-hr Cu^{61} has been measured by the method of atomic beam. The isotope was produced with the $(\alpha 2n)$ reaction by bombarding Co^{60} with the 34-Mev α beam from the Berkeley 60-in. cyclotron. Chemistry was performed to separate the Cu metal from the Co target. Resonances were observed by inducing transitions between the $m_F=-1$ and $m_F=-2$ members of the $F=2$ levels, at fields of 57, 111, 126, 176, and 239 gauss. The radioactive atoms were collected on sulfur-coated buttons which were counted in sodium iodide crystal scintillation counters. $\Delta\nu$ was calculated using the Breit-Rabi formula, assuming positive and negative values of g_I. The assumed positive value of g_I gave the best fit to the data and resulted in a $\Delta\nu=11\,200\pm400$ mc/sec. Using the

Fermi-Segrè formula and the results of Cox and Williams,[1] the magnetic moment of Cu^{61} was found to be: $\mu = +2.12 \pm 0.08$ nm.

* Supported in part by the Air Force Office of Scientific Research and the U. S. Atomic Energy Commission.
[1] H. L. Cox and D. Williams, Bull. Am. Phys. Soc. Ser. II, 2, 30 (1957).

D6. Nuclear Spin of Samarium-153.* AMADO CABEZAS, EDGAR LIPWORTH, RICHARD MARRUS, AND JOSEPH WINOCUR, *University of California, Berkeley.*—Hyperfine structure investigations of 47-hr Sm^{153} by the atomic-beam magnetic-resonance technique indicate that the nuclear spin of this nuclide is $I = \frac{3}{2}$. In a low field search, three resonances were observed which were ascribed to transitions occurring in the $J = 1$ and $J = 2$ excited electronic states. With the flop-in magnet geometry used in this experiment, these resonances must be of a multiple quantum character. Each of the transitions was observed at three fields. The data indicate that the g_J value of both observed electronic states is 1.5, the value obtained in pure L-S coupling among the electrons of the configuration $(5f)^6$. This configuration is the same as that inferred from optical spectroscopy.

* This research sponsored under the auspices of the U. S. Atomic Energy Commission and the Air Force Office of Scientific Research.

D7. Nuclear Spin-Lattice Relaxation Caused by Paramagnetic Impurities.* W. E. BLUMBERG,† *University of California, Berkeley.*—The behavior of the nuclear magnetization following the application of a saturating pulse of radio-frequency magnetic field is considered in three cases: (1) relaxation via paramagnetic impurities in the absence of nuclear spin diffusion, (2) relaxation which is limited by diffusion, and (3) relaxation in which diffusion is rapid. The first two cases lead to relaxation rates which vary with time. Only the latter two cases are of physical importance. A solution for the first case, however, suggests that, for a very short time after saturation, the nuclear magnetization will be proportional to $t^{\frac{1}{2}}$ in the second case. A pulsed nuclear resonance experiment on the protons in NH_4HSO_4 doped with Cr^{3+} ions verified this expected behavior. For concentration of Cr^{3+} ranging from 5×10^{17} to 10^{19} per cm^3, this transient solution was valid for the first 0.2 sec following saturation. These measurements also allow determination of the relaxation time of the Cr^{3+} ions introduced into NH_4HSO_4, 10^{-3} sec, and the nuclear spin diffusivity of the protons, 10^{-14} cm^3/sec.

* Supported in part by the Office of Naval Research and the National Security Agency.
† Present address: Bell Telephone Laboratories, Murray Hill, New Jersey.

D8. Nuclear Magnetic Resonance of Be^9 in Polycrystalline BeO.* J. F. HON, *Atomics International.*—The nuclear magnetic resonance (NMR) of Be^9 has been observed in samples of hot-pressed, powdered BeO having densities greater than 99% of theoretical density. The resonance in the samples, after pressing and subsequent annealing, displayed a long spin-lattice relaxation time (several minutes). In order to facilitate measurement, the samples were γ-irradiated.[1] The observed resonance (derivative) showed two pairs of satellite responses. This is contrary to what would be expected on the bases of (1) isotropic distribution of crystallite orientation and (2) the structure of BeO as deduced from x-ray data.[2] However, some samples displayed marked striations, and x-ray data indicated a tendency for preferential orientation of the c axis of the crystallites along the direction of the striations. A study of one of these samples revealed only one satellite response when the striations were perpendicular to the NMR polarizing field and a more complex double satellite response with the striations nearly aligned with the NMR polarizing field. These results show a violation of condition (1) above.

* This research was supported by the U. S. Atomic Energy Commission.
[1] J. F. Hon and P. J. Bray, Phys. Rev. 110, 624 (1958).
[2] Jeffrey, Parry, and Mozzi, J. Chem. Phys. 25, 1024 (1956).

D9. Measurement of the Proton Population Readjustment Time in the Overhauser Effect of Free Radicals.* ROBERT S. RHODES AND JAMES H. BURGESS, *Stanford University.*—The nuclear population distribution undergoes a transient readjustment following a change in the electronic saturation factor in materials exhibiting the Overhauser effect. Measurements have been made of the readjustment time τ for protons in three organic free radicals in a magnetic field of 3100 oe. The power applied to the electronic transition was chopped at a variable audiofrequency. Proton absorption was observed with a marginal oscillator and phase-sensitive detector. The output signal was proportional to the difference between enhanced and normal nuclear absorption. The decrease of the output with increasing chopping frequency served to determine τ. The results for the free radicals DPPH, BDPA, and picryl-amino carbazyl are respectively 1.2 ± 0.2, 1.3 ± 0.3, and 1.6 ± 0.3 msec. Since the electronic spin-lattice relaxation time is 10^{-4} times that of the protons, the observed τ should be equal to the proton T_1. For DPPH, τ agrees closely with a pulse measurement[1]: $T_1 = 1.4(\pm 0.1) \times 10^{-3}$ sec. Although the technique described here can be used to measure the enhancement of the nuclear resonance, additional information is required to determine the branching ratios for the various nuclear relaxation paths.

* Supported by the U. S. Air Force Office of Scientific Research.
[1] I. J. Lowe (private communication).

THURSDAY AFTERNOON AT 1:45

Crawford 103

(R. LATTER presiding)

Invited Papers on Atomic Physics II

E1. Application of Thermal Inelastic Collision Cross Section to the Analysis and Composition of Stellar Atmospheres. R. N. THOMAS, *National Bureau of Standards.* (25 min.)

E2. Scattering of Electrons by Atoms. S. BOROWITZ, *New York University.* (25 min.)

E3. Theoretical Methods for Calculation of Atomic Collision Cross Sections. M. H. MITTLEMAN, *University of California, Livermore.* (25 min.)

E4. Methods for Calculation of Opacities. W. KARZAS, *Rand Corporation.* (25 min.)

E5. Radar Studies of the Ionosphere. A. M. PETERSON, *Stanford University.* (25 min.)

E6. Discussion. R. LATTER, *Rand Corporation;* B. LIPPMANN, *University of California, Livermore;* J. W. BOND, JR., *Convair.* (30 min.)

THURSDAY AFTERNOON AT 2:00

Crawford 105

(L. WILETS presiding)

Invited Papers on Low-Energy Nuclear Physics II

F1. Inelastic Scattering and Collective Excitations in Light and Intermediate Nuclei. G. W. FARWELL, *University of Washington, Seattle.* (20 min.)

F2. Nucleon Clustering and Models of Light Nuclei. D. R. INGLIS, *Argonne National Laboratory.* (20 min.)

F3. Excited Configurations in Light Nuclei. I. TALMI, *The Weizmann Institute of Science.* (20 min.)

F4. Direct Radiative Capture in Light Nuclei. G. M. GRIFFITHS, *University of British Columbia.* (20 min.)

F5. Measurements of Nuclear g Factors of Excited States of Nuclei. G. MANNING, *California Institute of Technology.* (20 min.)

THURSDAY AFTERNOON AT 1:45

Crawford 209

(A. PAIS presiding)

High-Energy Nuclear Physics

Invited Paper

G1. Experience with Hydrogen Bubble Chambers at Berkeley. H. BRADNER, *University of California, Berkeley.* (30 min.)

Contributed Papers

G2. 4.15 Bev Proton-Proton Scattering in Nuclear Emulsions.* M. H. BLUE, C. Y. KIM, J. J. LORD, AND C. H. TSAO, *University of Washington.*—In a stack of Ilford G-5 emulsions exposed to the 4.15-Bev internal proton beam of the Bevatron about 400 events have been found by following light secondaries[1] and by area scanning. About half of these events have been discarded as being collisions with protons bound in heavy emulsion nuclei because of their having decay electrons or blobs which could be due to the recoil of fragments of heavy nuclei. Measurements of the scattered angles, ionization loss, and scattering of the secondary particles have been made on 20 elastic appearing, 37 two prong inelastic, 25 four prong, and 1 six prong event. These data are uncorrected for scanning efficiency. Center-of-mass angular distributions of the elastic scattering and of the angular distribution and momentum spectrum of the charged pions produced will be shown.

* Assisted by the National Science Foundation and the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

[1] Kalbach, Lord, and Tsao, Phys. Rev. **113**, 325 and 330 (1959).

G3. Lifetimes and Asymmetries of Σ Hyperon Decays.* STANLEY C. FREDEN, HARRY N. KORNBLUM, AND R. STEPHEN WHITE, *University of California, Livermore.*—The study of the decays of Σ hyperons produced by the interactions of K^- mesons stopped in nuclear emulsions has been extended. Only those hyperons from two-pronged $\Sigma^{\pm}\pi^{\mp}$ events were selected for analysis. $117\Sigma^+$ decays into protons, $94\Sigma^+$ decays into π^+ mesons, $17\Sigma^-$ decays into π^- mesons, and $32\Sigma^{\pm}$ decays into $\pi^{\pm}$ mesons have been observed. The mean lifetimes obtained for all Σ^+ decays into protons, for Σ^+ decays in flight into protons, and for Σ^+ decays in flight into π^+ mesons are, respectively: $8.47_{-1.06}^{+1.41}\times10^{-11}$ sec, $9.5_{-4.3}^{+22.9}\times10^{-11}$ sec, and $5.8_{-2.2}^{+8.5}\times10^{-11}$ sec. Applying a cutoff at 5×10^{-11} sec to the decays in flight does not change the lifetimes significantly. These values are in agreement with the presently accepted value of the Σ^+ lifetime. Possible reasons for the apparent short lifetime previously obtained by this group and by others will be discussed. The asymmetry parameter α, defined by $P(\alpha)=1+\alpha\sin\beta\cos\phi$ where θ is the production angle in the c.m. system and ϕ is the angle between the π meson secondary and the normal to the production plane in the c.m. system, has the following values for the Σ^+ decays into protons, the Σ^+ decays into π^+ mesons, and the Σ^- decays in π^- mesons, respectively: 0.07 ± 0.30, -0.06 ± 0.27, $-0.35_{-0.57}^{+0.61}$. All the errors quoted above except those for the lifetime for all Σ^+ decays into protons are 50% confidence limits of the probability distributions.

* Work done under the auspices of the U. S. Atomic Energy Commission.

G4. Proton Helicity from Λ^0 Decay.* R. W. BIRGE AND WILLIAM B. FOWLER, *University of California, Berkeley.*—It has been pointed out[1] that the longitudinal polarization of the proton from the decay of unpolarized hyperons at rest equals $-\alpha$, where α is the asymmetry parameter governing the angular distribution of the decay of polarized hyperons and is a measure of parity mixing. Because the decay in flight of Λ hyperons leads to a partial transverse polarization of the decay proton in the laboratory system, the sign of α may be determined by noting the left-right asymmetry in a subsequent scatter. We have analyzed 78 elastic and quasi-elastic scatters of protons resulting from well-measured Λ decays obtained from a sample of about 300 events. These events, and others to be reported on, were included in a group of about 20 000Λ's obtained in a high-energy K^- beam[2] using the Lawrence Radiation Laboratory 30 in. propane bubble chamber. A plot of the maximum likelihood function

$\pi_{i=1}^{N}(1+\alpha P_i)$ based on 37 events with a polarizability P_i greater than 0.2 peak at $\alpha=0.73+0.27-0.52$ and indicates that the proton has a negative helicity in agreement with other results.[3]

* Work done under the auspices of the U. S. Atomic Energy Commission.
[1] T. D. Lee and C. N. Yang, Phys. Rev. **108**, 1645 (1957). J. Leitner, Noise Control **8**, No. 10, 68 (1958).
[2] M. L. Good and H. K. Ticho (unpublished).
[3] Boldt, Bridge, Caldwell, and Pal, Phys. Rev. Letters **1**, 256 (1958).

G5. High Nuclear Excitation as a Nuclear Force Probe.* D. B. BEARD, *University of California, Davis.*—Nuclear evaporation experiments for excitation energies greater than about 20 Mev have revealed much more rapid increases of nuclear level densities with energy than simple theory predicts. The validity of the application of statistical methods and the compound nucleus assumption for these energies and for isotropic particle emission has been indicated by several authors. The source of the discrepancy between simple theory and experiment lies rather in the assumed form of the individual particle model. The simple theory and most elaborations on it assume that the individual particle levels are evenly distributed with high degeneracy. In actuality the levels must be assumed to have decreasing spacing with increasing excitation energy due to the diffuse nuclear wall rather than the harmonic oscillator or square wall, which gives rise to evenly spaced levels. The nuclear level spacing is very sensitively dependent on the individual particle level spacing and may be used to infer the actual individual particle level density. Since this latter quantity is a unique characteristic of the nuclear potential radius and shape, properly analyzed particle distributions from nuclei excited to about 50 Mev can uniquely establish the actual force field bound particles experience when excited.

* Supported in part by the U. S. Atomic Energy Commission.

G6. Charge Independence in Associated Production.* FRANK S. CRAWFORD, JR., ROGER L. DOUGLASS, MYRON L. GOOD, GEORGE R. KALBFLEISCH, M. LYNN STEVENSON, AND HAROLD K. TICHO, *University of California, Berkeley.*—If charge independence (CI) holds in $\pi^+ + p \to \Sigma^+ + K^+$, $\pi^- + p \to \Sigma^- + K^+$, and $\pi^- + p \to \Sigma^0 + K^0$, the triangle inequality $(\sigma^+)^{\frac{1}{2}} + (\sigma^-)^{\frac{1}{2}} - (2\sigma^0)^{\frac{1}{2}} \geq 0$ must be satisfied at all production angles. Previous results of Brown *et al.*[1] for incident π's of 1.23 Bev/c (1.1 Bev) indicated failure of CI for backward Σ's. We have measured σ^- and σ^0 at 1.23 Bev/c. Our results differ substantially from those of Brown *et al.* When we combine our results with the σ^+ results of Brown *et al.* we find agreement with the triangle inequalities and charge independence.

* This work done under the auspices of the U. S. Atomic Energy Commission.
[1] Brown, Glaser, Meyer, Perl, and Velde, Phys. Rev. **107**, 906 (1957).

G7. Photopion Production from Deuterium and the π^-/π^+ Ratio.* JOHN D. ANDERSON, DUANE C. GATES, THOMAS L. JENKINS, ROBERT W. KENNEY, AND WILLIAM P. SWANSON, *University of California, Berkeley.*—The reactions $\gamma + D \to \pi^- + 2P$ and $\gamma + D \to \pi^+ + 2N$ have been studied near threshold by observing 2- and 3-prong stars and $\pi^+ \to \mu^+ + \nu$ decays, respectively, in a 4-inch deuterium bubble chamber, as previously reported.[1] The preliminary value $\sigma(\pi^-)/\sigma(\pi^+) = 1.53 \pm 0.21$, uncorrected for Coulomb effects, was obtained for stopping mesons with a laboratory-system energy distribution 6.4 ± 2.7 Mev and an approximately isotropic angular distribution (lab). An approximate final-state Coulomb correction reduces the above value of 1.38 ± 0.19. Applying a technique due to Chew and Low[2] for extrapolating measurements on the reaction $\gamma + D \to \pi^- + 2P$ into the nonphysical region gave a free-nucleon total cross section $\sigma(\gamma + N \to \pi^- + P)$ of 70 ± 40 μb at an effective photon energy (lab) 161 ± 6 Mev. Comparing this cross-section value with that for the reaction[3] $\gamma + P \to \pi^+ + N$ gave the free-nucleon ratio $\sigma(\pi^-)/\sigma(\pi^+) = 1.5 \pm 1.0$. The momentum distribution (lab) of the less energetic proton in the final state of the reaction $\gamma + D \to \pi^- + 2P$ agrees qualitatively with the distribution given by Hulthen deuteron wave function. Improved statistics and additional data on the nucleon recoil distribution will be presented.

* Work done under the auspices of the U. S. Atomic Energy Commission
[1] Anderson, Gates, Jenkins, Kenney, and Swanson, Bull. Am. Phys. Soc. Ser. II. **4**, 274 (1959).
[2] G. F. Chew and F. E. Low, Phys. Rev. **113**, 1640–1648 (1959).
[3] H. A. Bethe and F. de Hoffman, *Mesons and Fields* (Row, Peterson, and Company, Evanston, Illinois, 1955), p. 153.

G8. Nuclear Excitation Induced by μ^--Meson Capture.* SELIG KAPLAN, BURNS MACDONALD, BURTON J. MOYER, ROBERT V. PYLE, AND JUSTO DIAZ, *University of California, Berkeley.*—The multiplicity distribution of neutrons emitted when a μ^- meson undergoes nuclear capture has been measured for several elements with a momentum-analyzed meson beam from the Berkeley 184-in. cyclotron. The neutrons were counted by observing capture γ's in a Cd-loaded liquid scintillator.[1] Preliminary calculations of average multiplicities give

$$\bar{\nu}_{Pb} = 1.60 \pm 0.06, \quad \bar{\nu}_{Au} = 1.56 \pm 0.06, \quad \bar{\nu}_{I} = 1.40 \pm 0.06,$$
$$\bar{\nu}_{Ag} = 1.45 \pm 0.06, \quad \bar{\nu}_{Fe} = 1.11 \pm 0.05.$$

Results from additional data on the foregoing elements plus Al, together with the multiplicity distributions, will be given at the meeting. Interpretation of the results in terms of simple nuclear models will also be discussed.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
[1] Kaplan, Moyer, and Pyle, Phys. Rev. **112**, 968 (1958).

G9. Search for Leptonic Decay Modes of $\Sigma^{\pm}$.* J. LEITNER,† P. NORDIN, JR., A. ROSENFELD, F. SOLMITZ, AND R. TRIPP, *University of California, Berkeley.*—As part of a continuing study of K^- absorption in hydrogen, we have searched for evidence of Σ leptonic decay modes. The selected sample consisted of only well-measured events—$750\Sigma^-$ and $250\Sigma^+ \to \pi^+ + n$ (effectively $500\Sigma^+$). The search was carried out by studying the (lab) momentum distribution of the Σ-decay products. The observed distribution was roughly Gaussian, centered about 190 Mev/c, the value expected for $\Sigma^{\pm} \to \pi^{\pm} + n$. We chose a detection cutoff at 100 Mev/c, just below the tail of the spectrum due to small-angle single Coulomb scattering; 45% of the leptonic phase-space spectrum falls below 100 Mev/c. We have found no decays below 115 Mev/c among $(0.45 \times 750 =)$ 335 effective Σ^- and 225 effecitve Σ^+, so that the upper limits of leptonic branching fractions are

$$f(\Sigma^- \to \mu^- + \nu + n) \leq 0.3\%,$$
$$f(\Sigma^+ \to \mu^+ + \nu + n) \leq 0.45\%.$$

* Work supported in part by the U. S. Atomic Energy Commission and Office of Scientific Research.
† On leave from Syracuse University.

G10. $\bar{p}$-p Cross Sections at High Energies.* RAFAEL ARMENTEROS,† CHARLES A. COOMBES, BRUCE CORK, GLEN R. LAMBERTSON, AND WILLIAM A. WENZEL, *University of California, Berkeley.*—The antiproton-proton interaction has been studied at 1.0, 1.25, and 2.0 Bev kinetic energy. The antiprotons were separated from the faster particles in the beam by an accurate time-of-flight measurement using scintillation counters and by use of the pulse from a gas Čerenkov counter in anticoincidence. The method, similar to that in a previous experiment,[1] employed a liquid hydrogen target completely surrounded by scintillation counters. Values of total, differential elastic, inelastic, and charge-exchange cross sections have been obtained. Preliminary values for the $\bar{p}$-p total cross section are 97, 90, and 70 mb at 1.0, 1.25, and 2.0 Bev, respec-

tively. The statistical uncertainty in each of these measurements is about 5 mb.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
† On leave of absence from Laboratoire de Physique, Ecole Polytechnique, Paris and CNRS, France.
[1] Coombes, Cork, Galbraith, Lambertson, and Wenzel, Phys. Rev. 112, 1303 (1959).

G11. Antiproton Interactions in Propane below 200 Mev.* L. AGNEW, T. ELIOFF, WILLIAM B. FOWLER, L. GILLY,† R. LANDER, L. OSWALD, WILSON M. POWELL, E. SEGRÈ, H. STEINER, H. WHITE, C. WIEGAND, AND T. YPSILANTIS, *University of California, Berkeley.*—In an experiment performed with the Berkeley 30-in. propane bubble chamber, 222-Mev antiprotons were brought to rest. Preliminary reports have been made on $\bar{p}p$ and $\bar{p}C$ elastic scattering and annihilation cross sections, and on the details of the hydrogen annihilation.[1] Final analysis has resulted in an appreciable change in the $\bar{p}p$ elastic cross section: we now report $\sigma_{el}(\bar{p}p) = 66 \pm 17$ mb for antiproton kinetic energy $75 \leq T_{\bar{p}} \leq 137.5$ Mev, and $\sigma_{el}(\bar{p}p) = 56 \pm 14$ mb for $137.5 \leq T_{\bar{p}} \leq 200$ Mev. Seventeen definite and five possible strange particles have been identified among the products of 436 annihilations. This indicates that the production of a pair of K mesons occur in $4.0 \pm 1.2\%$ of all annihilations ($\bar{T}_{\bar{p}} = 70$ Mev). The average total energy per K pair is >1200 Mev. The details of the carbon annihilation have been observed in 337 annihilations. Pion energy spectra and pion frequency distributions have been obtained. The principal products per annihilation include $1.58 \pm 0.07\pi^-$ with average total energy $\bar{E}_{\pi^-} = 366 \pm 13$ Mev, $1.33 \pm 0.08\pi^+$ with $\bar{E}_{\pi^+} = 371 \pm 13$ Mev, and $1.15 \pm 0.30\pi^0$ with $\bar{E}_{\pi^0} = 342 \pm 90$ Mev.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
† On fellowship from Institut Interuniversitaire des Sciences Nucléaires (Belgium). Now at Université de Louvain, Belgium.
[1] Agnew, Elioff, Fowler, Gilly, Lander, Oswald, Powell, Segrè, Steiner, White, Wiegand, and Ypsilantis, Phys. Rev. 110, 994 (1958); Phys. Rev. Letters 1, 27 (1958); Bull. Am. Phys. Soc. Ser. II, 3, 402 (1958).

FRIDAY MORNING AT 9:30

Crawford 103

(E. L. HAHN presiding)

Invited Papers on Radio-Frequency Spectroscopy I

H1. Interpretation of Nuclear Magnetic Relaxation Measurements in Low-Temperature Gases and Liquids I. M. BLOOM, *University of British Columbia.* (10 min.)

H2. Interpretation of Nuclear Magnetic Relaxation Measurements in Low-Temperature Gases and Liquids II. I. OPPENHEIM, *National Bureau of Standards.* (10 min.)

H3. Nuclear Magnetic Resonance Line Shape in CaF_2. R. E. NORBERG, *Washington University.* (25 min.)

H4. Hyperfine and Zeeman Transitions in Rubidium-87 Vapor. P. L. BENDER, *National Bureau of Standards.* (25 min.)

H5. Statistical Mechanics of Spin-Spin Relaxation. E. T. JAYNES, *Stanford University.* (25 min.)

H6. Nonresonant Microwave Absorption in Dilute and Compressed Gases. G. BIRNBAUM, *Hughes Aircraft Company.* (25 min.)

H7. Audio-Frequency Spin Absorption in Nuclear Spin Systems. A. G. ANDERSON, *I.B.M. Research Laboratory.* (25 min.)

FRIDAY MORNING AT 9:45

Crawford 105

(E. M. MCMILLAN presiding)

Invited Papers on High-Energy Nuclear Physics I

I1. Interactions of Strange Particles. A. PAIS, *Institute for Advanced Study.* (40 min.)

I2. Recent Results on K^- Meson Absorption in Hydrogen and Deuterium. D. H. MILLER, *University of California, Berkeley.* (20 min.)

I3. Interactions of K_2^0 Mesons in Nuclei. F. MULLER, *University of California, Berkeley.* (15 min.)

I4. Recent Results on Neutral Decay Modes of Strange Particles Observed in a Xenon Bubble Chamber. D. A. GLASER, *University of Michigan.* (15 min.)

I5. Design of an Experiment on the Limits of Quantum Electrodynamics by Means of Colliding 500-Mev Electron Beams. G. K. O'NEILL, *Princeton University.* (30 min.)

FRIDAY MORNING AT 10:00

Crawford 209

(G. T. SEABORG presiding)

Low-Energy Nuclear Physics

J1. Inelastic Scattering of High-Energy Protons. K. NISHIMURA, *Rutgers University.*—We have calculated the differential scattering cross section and polarization of high-energy nucleons exciting a collective level of the target nucleus. The nucleon-nucleon interaction was represented by a spheroidal square well potential with a complex depth plus the conventional spin-orbit coupling term. Since the Born approximation is known to fail near the diffraction minimum, an approximate calculation using the distorted waves was carried out in such a way that the results are more reliable in this region rather than for small scattering angles. A comparison with the experimental data at 185 Mev shows a reasonable agreement if the well parameters take the values given by the exact phase shift analysis of elastic scattering experiments. The effects of the well parameters on the polarization curve will be qualitatively discussed.

J2. Elastic and Inelastic Scattering of Neutrons from C^{12}.* E. HADDAD AND D. D. PHILLIPS, *University of California, Los Alamos.*—Angular distributions of elastically and inelastically scattered neutrons from C^{12} were determined at neutron bombarding energies of 6.0, 6.3, and 7.9 Mev. The measurements were made with a pulsed-beam time-of-flight spectrometer.[1] The elastic angular distributions exhibit pronounced peaking in the forward direction accompanied by smaller secondary maxima and minima. Within experimental error (about $\pm 10\%$) the inelastic differential cross sections associated with the 4.43-Mev state in C^{12} are symmetric about 90° in the center-of-mass system for 6.3- and 7.0-Mev incident neutrons, while the inelastic distribution at 6.0 Mev are asymmetric. The qualitative features of the inelastic angular distributions indicate that the $C^{12}(n,n')C^{12*}$ reaction proceeds predominantly by compound nucleus formation. Values for the total elastic and total inelastic cross sections at 6.0, 6.3, and 7.0 Mev are as follows:

Mev	σ_{el}(barns)	σ_{inel}(barns)
6.0	0.81 ± 0.08	0.24 ± 0.02
6.3	1.24 ± 0.12	0.35 ± 0.04
7.0	0.52 ± 0.05	0.17 ± 0.02

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] L. Cranberg and J. S. Levin, Phys. Rev. **103**, 343 (1956).

J3. Differential Cross Section for the $D(d,n)He^3$ Reaction.* MURREY D. GOLDBERG AND JAMES M. LEBLANC, *University of California, Livermore.*—The absolute differential cross section for production of monoenergetic neutrons by the $D(d,n)He^3$ reaction has been measured with 5.0-, 7.6-, 9.6-, and 12.2-Mev deuterons from the Livermore variable-energy cyclotron. A proton recoil counter telescope was used to detect the neutrons and to separate out neutrons from the $D(d,np)D$ breakup reaction. The distributions at all energies are very peaked in the forward direction, with a first minimum around 30 to 40 degrees and a subsequent smaller maximum. The angular distributions, transformed to the center-of-mass system, have been fitted with the exchange stripping theory of Owen and Madansky,[1] properly antisymmetrized to account for the identity of the incident and target particles. Excellent fits were obtained, but it was necessary to monotonically decrease the interaction radius, R_0, with incident deuteron energy. The variation was considerable, from $R_0 = 8.4 \pm 0.2$ fermi at 5.0 Mev to $R_0 = 5.5 \pm 0.2$ fermi at 12.2 Mev. An isotropic contribution of about 3 mb/sterad was added to each distribution to obtain the best fit.

* Work done under the auspices of the U. S. Atomic Energy Commission.
[1] G. E. Owen and L. Madansky, Phys. Rev. **105**, 1766 (1957).

J4. Studies of Complex Stripping Reactions of Heavy Ions.* RICHARD KAUFMANN AND RICHARD WOLFGANG, *Yale University.*—Stripping reactions of 160 Mev O^{16}, 140 Mev N^{14}, and 120 Mev C^{12} with a number of targets have been studied. The products of such reaction were identified by their recoil ranges which approximated the residual range of the bombarding heavy ions. Thus O^{16} bombardment gave rise to F^{18}, N^{13}, and C^{11} stripping products in yields somewhat smaller than that of the single nuclear stripping product O^{15}. A remarkable feature of the results is that with a wide range of targets and projectiles the yield ratios of $(p,2n)$ to (n), and $(2p,3n)$ to (n) stripping are approximately constant. A mechanism for these complex stripping reactions is proposed. The predictions of this mechanism are compared with experimental results on the angular distribution of the stripped products.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

J5. Reaction of High-Energy C^{12}, N^{14}, and O^{16} with Carbon.* MURRY TAMERS AND RICHARD WOLFGANG, *Yale University.*—The reactions of 160-Mev O^{16}, 140-Mev N^{14}, and 120-Mev C^{12} to yield radioactive products have been studied and the results compared with those for proton-induced reactions giving formally similar compound systems. Excitation functions for products formed at low energies are similar in the corresponding proton and heavy ion cases, indicating that their formation involved similar low-energy, low-spin compound nuclei. However no "tail" due to knock-on cascade processes was observed with heavy ions. Yields for higher energy products, chiefly F^{18}, were much higher in the heavy ion bombardment. This is attributed partly to higher average energy deposition with heavy ions due to the absence of knock-on processes and to enhanced alpha emission from the distorted high-spin nuclei formed by heavy ions. The contribution of various stripping processes to the observed yield is discussed.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

J6. Total Reaction Cross Section in Heavy Elements.* J. W. COBBLE, R. GUNNICK, M. J. LASALLE, AND L. J. COLBY, JR., *Purdue University.*—Accurate values of the total reaction and fission cross sections of 20–50 Mev alpha particles on U^{233}, U^{235}, U^{238} have been obtained by radiochemical methods. The data have been used to obtain nuclear radii based upon the Weisskopf treatment of the square-well nuclear potential. The agreement with this theory is excellent, and results in a radius parameter, $R^0 = 1.52$ fermis. Comparison of this data with that of comparable accuracy at other masses for alpha-particle induced reactions[1] indicates a small but apparently real decrease in R^0 with decreasing mass number. The effect of using a diffuse nuclear potential for the calculations of R^0 will be discussed.

* Supported by the U. S. Atomic Energy Commission.
[1] Corrected for more recent and accurate range-energy data of alpha particles.

J7. Neutron Absorption Cross Sections with Sb-Be Neutrons.* C. W. Cook, *Convair*, and H. W. Schmitt, *Oak Ridge National Laboratory.*—Spherical shell transmission measurements[1] employing Sb-Be neutrons have been used to obtain absolute neutron absorption cross sections for the elements cadmium, indium, iodine, and mercury. The specially designed Sb-Be source has been found[2] to emit neutrons with a mean energy of 24.3±2 kev. The neutron detectors consisted of modified long counters which were shielded by lead from source gamma rays. Transmission measurements were made by using solid spherical shells of cadmium and indium and hollow shells of thin aluminum filled with mercury and elemental iodine. Multiple scattering in the sample shells was treated according to the method of Bethe, Beyster, and Carter[3] and corrections were applied for finite source dimension, finite source to detector distance, absorptions in the source, and resonance self-shielding. Preliminary absorption cross sections are: cadmium, 390±60 mb; indium, 840±125 mb; iodine, 790±120 mb; and mercury, 325±50 mb.

* Work performed at the Oak Ridge National Laboratory and supported in part by the Convair Scientific Research Laboratory.
[1] Schmitt, Gibbons, and Inskeep, Bull. Am. Phys. Soc. Ser. II, **4**, 43 (1959).
[2] H. W. Schmitt (to be published).
[3] Bethe, Beyster, and Carter, J. Nuclear Energy **3**, 207 (1956); **3**, 273 (1956); **4**, 3 (1957); **4**, 147 (1957).

J8. Velocity Distribution of the Charged Products of the *d-d* Reaction in Scylla.* D. E. Nagle, W. Leland, W. E. Quinn, and W. B. Riesenfeld, *Los Alamos Scientific Laboratory.*—Protons from the *d-d* reaction in Scylla have been observed in the axial direction using nuclear photographic emulsions. In one arrangement a pinhole camera is used to study the spatial location and extent of the source. In a second experiment a 60-degree magnetic spectrometer is used to measure the velocity distribution of the protons emitted along the axial direction. One spectrograph plate has been exposed in which 847 tracks have been found. Their velocity distribution may be used to infer the spread in the velocity of the center of mass of the reacting deuterons, which appears to be considerable. The details of the relationship between the observed velocity distribution and the center of mass velocity distribution will be discussed.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

J9. Elastic Scattering of Alpha Particles by N^{15}.* H. Smotrich,† K. W. Jones,‡ L. C. McDermott, and R. Benenson,§ *Columbia University.*—The absolute differential cross sections for the elastic scattering of alpha particles by N^{15} have been measured at six center-of-mass angles for alpha-particle energies from 1.75 Mev to 5.49 Mev.[1] In this study thirty levels corresponding to the compound nucleus F^{19} were observed. The first 16 of these levels have been analyzed using Wigner-Eisenbud reaction theory for the case of elastic scattering of spin 0 particles from spin ½ nuclei. The resulting assignments of resonant energies (Mev), spins and parities are: 1.878, $3/2^+$; 2.614, $5/2^+$; 2.635, $5/2^-$; 2.833, $1/2^+$; 2.883, $5/2^+$; 2.944, $7/2^+$; 3.07, $1/2^-$; 3.194, $1/2^+$; 3.229, $5/2^+$; 3.525, $3/2^-$; 3.587, $5/2^+(3/2^+)$; 3.648, $5/2^-$; 3.705, $9/2^-(7/2^-)$; 3.78, $1/2^-$; 3.92, $7/2^+$; 3.94, $3/2^+$.

* This work was partially supported by the U. S. Atomic Energy Commission.
† Now at Air Force Special Weapons Center, Kirtland Air Force Base, New Mexico.
‡ Now at The Ohio State University.
§ Permanent address: The City College of New York.
[1] Smotrich, Jones, McDermott, and Benenson, Bull. Am. Phys. Soc. Ser. II, **3**, 26 (1958).

J10. (n,p) Reaction for Zirconium at 14 Mev.* Se Hee Ahn,† J. R. Hearst, J. H. Roberts, and E. N. Strait, *Northwestern University.*—The energy and angular distributions of the protons from the interaction of 14.1-Mev neutrons with zirconium have been obtained using nuclear emulsion plates. The Northwestern University electrostatic accelerator was used with a tritium gas target to produce neutrons by $H^3(d,n)He^4$. The neutron beam was collimated by a two-foot stack of steel plates with a tapered hole, and the multiple plate camera was shielded by an 8-in. paraffine wall. The significance of these results in terms of the compound nucleus and direct interaction models will be discussed. The data, also, will be compared with the previous results[1] of the (n,n') reaction for zirconium at 14.1 Mev.

* Work supported by the U. S. Atomic Energy Commission through Argonne National Laboratory subcontract.
† On leave from Yonsei University, Seoul, Korea.
[1] Se Hee Ahn and J. H. Roberts, Phys. Rev. **108**, 110 (1957).

J11. Optical Model and the Correlated Nuclear Wave Function.* J. Dabrowski,† *Institute for Advanced Study and University of Washington*, and J. J. Sawicki, *Princeton University and University of Washington.*—Watson's multiple scattering theory is applied to calculate the well depths of the nuclear optical potential. The nulcear ground state is represented by a Jastrow-type wave function. The consequences of the Bethe-Goldstone equation for the correlation functions are considered. Our numerical results obtained for the case of a separable nucleon-nucleon interaction show that the effects of the correlations amount to corrections to the Fermi model case up to the order of 10% in the medium and high-energy range. The evaluated corrections due to the incoherent multiple scattering appear to be important. In the case of realistic two-body forces Galitski's equation is applied. This equation relating the free scattering t matrix to the t-matrix for the scattering in nuclear medium is solved by iterations. The effective single particle potential of Wada and Bey is applied. The real and imaginary well depths are computed for this case using the Fermi gas model.

* Supported in part by the U. S. Atomic Energy Commission and the Higgins Scientific Trust Fund.
† On leave of absence from the Institute for Theoretical Physics, Warsaw, Poland.

J12. Spectrum of Au^{197}.* Gaja Alaga,† *University of California, Berkeley.*—Using the pairing force[1] between 3 protons in the $s_{\frac{1}{2}}$ and $d_{\frac{3}{2}}$ states and the conventional collective description of the neutron vibrations up to two phonons and applying the intermediate coupling scheme,[2] we have calculated the spectrum of Au^{197}. Taking the difference between the single particle states from thallium the frequency of neutron vibration from lead and $G\sim(25/A)$ Mev[3] for the strength of the pairing force, we obtain a fair description of the known levels in Au^{197} and predict higher excited states. In the calculation the near lying states with $I=\frac{3}{2}$ and $I=\frac{5}{2}$ are inverted, which is not surprising in the approximation used. An attempt is being made to explain the differences in the $Au^{193,195,199}$ spectra in terms of the quasi-particle description.[1,3]

* This research was supported by the U. S. Atomic Energy Commission.
† On leave from the University of Zagreb and Institute Rudjer Boskovic, Yugoslavia.
[1] S. T. Belyaev, Kgl. Danske Videnskab. Selskab Mat.-fys. Medd. **31**, No. 11 (1958).
[2] D. C. Choudhury, Kgl. Danske Videnskab. Selskab Mat.-fys. Medd. **28**, No. 4 (1954).
[3] B. R. Mottelson, Lectures at the University of California, Berkeley (1959).

FRIDAY MORNING AT 9:00

George 226

(D. W. KERST presiding)

Satellites and Other Topics

Invited Paper

K1. The International Geophysical Year—Some Results. J. KAPLAN, *University of California, Los Angeles.* (30 min.)

Contributed Papers

K2. Flux and Energy of Charged Particles at 300- and 600-Mile Altitude.* A. H. ARMSTRONG, F. B. HARRISON, AND L. ROSEN, *Los Alamos Scientific Laboratory.*—Nuclear emulsions have been used to study the charged particles near the lower radiation belt.[1] One stack, $2\times2\times\frac{1}{4}$ in., was flown to a maximum altitude of 750 miles, and spent 15 min above 600 miles, at a mean latitude of 9.5°N. The flux of nonrelativistic protons of energy >70 Mev is >50 cm^{-2} sec^{-1} $sterad^{-1}$. The flux of electrons of energy >11 Mev is <5% of the above number. Another stack, $10\times4\times4$ in., was flown approximately 10 min near 300 miles altitude. The flux of nonrelativistic protons of energy >70 Mev is $\ll$10% of that observed at 600 miles altitude. We wish to acknowledge the excellent cooperation of the personnel of the General Electric Ballistic Missile Division; the AFBMD; and the Redstone Arsenal (ABMA).

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] Van Allen, Ludwig, Ray, and McIlwain, IGY Satellite Series No. 3, 73; Natl. Acad. Sci., Washington, D. C.

K3. Fermi Acceleration of Electrons in the Outer van Allen Belt.* J. A. CRAWFORD, *University of California, Berkeley.*—Interface instabilities associated with arriving and departing magnetic storm clouds generate a strong Fermi acceleration which "dumps" all van Allen electrons of the outer belt that are trapped on magnetic lines anchored in the earth. For this reason among others, the decay of albedo neutrons can account only for the inner belt which remains essentially undisturbed. This "sweeping" action of storms suffices to explain the presence of a gap between the belts. Thus the exterior electron belt must initially be trapped in the closed magnetic loops left behind by the decaying storm. These loops decay in turn, depositing their radiation in the geomagnetic field. The 1-ev storm electrons originally trapped in the loops undergo a Fermi acceleration produced by the departing cloud. This leads very quickly to high energies and accounts satisfactorily for the radiation observed in the outer belt, collisions between electrons being duly taken into account in the complete Fokker-Planck equation. Thus it is unnecessary to assume that this radiation must be transported somehow from the sun.

* Research supported by the U. S. Air Force Office of Scientific Research.

K4. Charge on a Body Moving in an Ionized Atmosphere with Pervading Magnetic Field.* S. F. SINGER, *University of Maryland,* AND K. P. CHOPRA, *University of Southern California.*—A body moving in an ionized atmosphere with a pervading magnetic field may acquire charge through collisions with ions and electrons, photoejection of electrons, and induced electric currents due to the motion across the magnetic lines of force. The phenomena have different behaviors at slow and fast speeds of the body. In the intermediate case, the calculations would be quite involved. A knowledge of the nature and amount of charge on a body is of interest in the problems concerning the dynamics of dust particles, meteors and meteorites, whistling atmospherics, and indeed the motion of artificial earth satellites. The relative importance of the various processes of charging under specified conditions is discussed. Some insight can be gained by performing simple experiments in a low-density wind tunnel. The principle of design of a method of estimating satellite charge (currently in progress at the University of Maryland) is briefly described.

* Supported in part by the U. S. Air Force Office of Scientific Research.

K5. Drag of an Artificial Earth Satellite.* RAYMOND L. CHUAN AND K. P. CHOPRA, *University of Southern California.*—Recently the problem of drag on an artificial satellite has been taxing the curiosity of several authors (references in the text). This paper discusses several physical processes which may contribute to the drag of an artificial satellite (or for that matter, any body) moving in an ionized atmosphere with a pervading magnetic field. These processes involve electromagnetic induction (induction drag), Coulomb scattering of charged particles (Coulomb drag), ionization caused by the satellite (ionization drag), the emission of plasma waves (wave drag), surface interactions with impinging particles (surface drag), etc., besides the direct collisions (neutral aerodynamic drag). An insight can be obtained by performing simple experiments in a low-density wind tunnel under specified conditions.

* Supported in part by the U. S. Air Force Office of Scientific Research.

K6. Refraction of Hydromagnetic Waves in the Geomagnetic Field. M. I. GREEN, W. E. FRANCIS, AND ALEXANDER J. DESSLER, *Lockheed Missiles and Space Division.*—It has been suggested that the world-wide sudden commencement of magnetic storms are propagated around the earth by means of longitudinal hydromagnetic waves.[1] These hydromagnetic waves are generated by the impact of the solar wind with the earth's magnetic field at a distance of about six earth radii on the sunlit hemisphere. The previous estimate[1] of the time required for the wave to propagate around the earth is now considered to be in error since the ray path chosen violates Fermat's principle of least time. In order to obtain a better estimate, the ray paths of hydromagnetic waves were traced between points several earth radii distant and points immediately above the earth's surface. For simplicity, the calculations were made for ray paths only in the equatorial plane. The hydromagnetic wave velocity *vs* radial distance was calculated from the $1/r^3$ magnetic field dependence and the ion density calculations of F. S. Johnson.[2] The transit times for the waves to propagate between distant points and points on the earth's surface were then obtained by utilizing Fermat's principle of least time and integrating the resulting nonlinear differential equation on an electronic computer.

[1] A. J. Dessler, J. Geophys. Research 63, 405 (1958).
[2] F. S. Johnson, Lockheed Missiles & Space Division Technical Report LMSD 49719 (April, 1959).
[3] V. B. Gerard, J. Geophys. Research 64, 593 (1959).

K7. Expansion of a Rarefied Gas into a Vacuum. PAUL MOLMUD, *Space Technology Laboratories.*—The expansion into a vacuum of a cloud consisting of a finite amount of gas is described. The analysis is based upon the assumption of free molecular flow. The solution is obtained for the expansion into a vacuum of an instantaneous point source of particles

initially having a Maxwellian velocity distribution. The solution is $\rho = N(\beta/\pi t^2)^{\frac{1}{2}} \exp(-\beta r^2/t^2)$ where ρ is the density, N the source strength and $\beta = M/2kT$. This solution is used to construct the solutions of other free expansion problems, namely spherical and cylindrical gas clouds, as well as the expansion of a gas which originally occupied half space. Expressions may be derived for the momentum and energy flow of such clouds. The neglect of collisions in the expansion of a spherical gas cloud is valid so long as the initial mean free path of a molecule is much greater than the initial diameter of the sphere. The expansion of a gas cloud in front of a specularly reflecting plane surface is treated by the method of images. The transformation $t^2/\beta \rightarrow 4Dt$ transforms a class of free molecular flow problems into diffusion and heat flow problems.

K8. Cratering and Jetting Phenomena due to the Impact of Mercury Spheres on Thick Plates. GERALD E. MELOY AND EARLE B. MAYFIELD, *U. S. Naval Ordnance Test Station* (introduced by Mr. William A. Allen).—Two millimeter diameter mercury spheres were impacted on aluminum plates twenty millimeters in diameter, by means of a moving target, stationary projectile system. The aluminum target was fired from a twenty millimeter smooth-bore cannon at velocities from 1 mm/μsec to 2 mm/μsec. Targets composed of 75 ST-6 and 24 ST-6 aluminum were used to determine the effect of the strength of the material on the crater dimensions. The time position history of the mercury with respect to the target was determined by use of a variable time delay spark shadowgraph. The craters formed were at variance with those predicted by theory. The crater approximated a sphere with the penetration greater than the radius of the sphere, while theory predicts a crater of spherical shape with the penetration less than the spherical radius. Results will be presented showing the crater volume as a function of kinetic energy, and momentum of the projectile.

K9. Experimental Observations of Overstable Cellular Convection.* Y. NAKAGAWA, *University of Chicago.*—The overstable (oscillatory) cellular convection which arises from thermal instability in a layer of mercury heated uniformly from below and subject to Coriolis forces has been studied. The observations have confirmed Chandrasekhar's theoretical predictions[1] regarding the wave number of the cells and of the characteristic period of the oscillatory motions. Further a detailed analysis of the movement of tracers has clearly illustrated the periodic reversal of the convective circulation and the hexagonal pattern of the convection cells.

* Research supported in part by the Office of Naval Research.
[1] S. Chandrasekhar, Proc. Roy. Soc. (London) **A217**, 306 (1953); S. Chandrasekhar and D. D. Elbert, *ibid.* **A231**, 198 (1955).

K10. Peculiarity of Shock Impingement on Area Convergence.* A. K. OPPENHEIM, P. A. URTIEW, AND R. A. STERN, *University of California, Berkeley* (introduced S. A. Schaaf).—General study of wave systems which can result from the interaction of plane shock with an area convergence has led to the discovery of an interesting regime, specified in terms of functional relationships between shock Mach numbers and area ratios, where two or three solutions exist at the same time, all satisfying the dynamic boundary conditions imposed by the conservation laws. The ambiguity is resolved by invoking the extremum principle of irreversible thermodynamics.

* This work was supported by the U. S. Air Force through the Air Force Office of Scientific Research of the Air Research and Development Command under Contract No. AF 49(638)-166.

FRIDAY AFTERNOON AT 1:45

Crawford 103

(W. A. NIERENBERG presiding)

Invited Papers on Radio-Frequency Spectroscopy II

L1. Overhauser Polarization Enhancements in Liquids. W. ANDERSON, *Varian Associates.* (25 min.)

L2. Radio-Frequency Spectroscopy of Atoms by Optical Orientation. R. NOVICK, *University of Illinois.* (25 min.)

L3. Induction-Type Experiments at Microwave Frequencies. A. M. PORTIS, *University of California, Berkeley.* (25 min.)

L4. Spin Resonance Studies of Certain Sapphires. C. KIKUCHI, *University of Michigan.* (25 min.)

L5. Some Novel Methods of Microwave Spectroscopy with Applications to Fine Structure Measurements. P. A. FRANKEN, *University of Michigan.* (25 min.)

FRIDAY AFTERNOON AT 1:45

Crawford 105

(J. R. RICHARDSON presiding)

Invited Papers on High-Energy Nuclear Physics II

M1. Photoproduction of Pions above 500 Mev. R. L. WALKER, *California Institute of Technology.* (15 min.)

M2. Experiments on Pion Photoproduction with Polarized X-Rays. R. F. MOZLEY, *Stanford University.* (15 min.)

M3. An Approach to the Theory of Strong Interactions. S. MANDELSTAM, *University of California, Berkeley.* (60 min.)

M4. Antiproton Interactions up to 1 Bev. T. YPSILANTIS, *University of California, Berkeley.* (20 min.)

M5. Present Status of Muon Physics. V. L. TELEGDI, *University of Chicago.* (20 min.)

FRIDAY AFTERNOON AT 2:30

Crawford 209

(H. A. SHUGART presiding)

Solid-State Physics

N1. Electron Density in Aluminum Oxide Contaminated Flames. M. D. PEARSON, O. W. LARSEN, W. J. LINDER, AND C. W. BOWLBY, *Boeing Airplane Company.*—The electron density in oxygen-acetylene flames contaminated with aluminum oxide powder has been measured by means of the microwave attenuation technique of Belcher and Sugden.[1] The attenuation of 30 000 Mc radiation by the flame is measured at two frequencies, and electron density and collision frequency are calculated by the simultaneous solution of two equations expressing the attenuation as a function of frequency, electron density, and collision frequency. Attenuations of the order of 1.5 db per cm are measured when aluminum oxide powder is injected into the oxygen supply line at rates of from 10 to 40 grams per minute. From these measurements the electron density is 3×10^{12} electrons per cm^3 and the collision frequency is 8×10^{11} collisions per second.

[1] H. Belcher and T. Sugden, Proc. Roy. Soc. (London) **A201**, 480 (1950).

N2. Kinetics of Crystallization on Surfaces. ERNST BAUER, *U. S. Naval Ordnance Test Station.*—The kinetics of crystallization on surfaces, which determines for instance the growth of thin films, is treated in a formal way, based upon the conception of the extended[1] quantities. General expressions are derived for the grain size distribution, the total number of grains, and the differential and mean condensation coefficients. For a simple case the condensation coefficients are calculated and compared with recent experimental results.[2,3]

[1] M. Avrami, J. Chem. Phys. **7**, 1103 (1939); **8**, 212 (1940); **9**, 177 (1941).
[2] Yang, Simnad, and Pound, Acta Met. **2**, 470 (1954).
[3] H. Walther, Z. angew. Phys. **10**, 272 (1958).

N3. Resistivity, Hall Effect, Electronic Specific Heat, and Superconductivity of Binary bcc Ti Alloys.* R. R. HAKE, D. H. LESLIE, AND T. G. BERLINCOURT, *Atomics International.*—Measurements between 1.1°K and 300°K on arc-melted bcc Ti-Mo alloys indicate very high resistivities, near zero or slightly negative temperature coefficients of resistivity down to the superconducting transition temperatures in the vicinity of 4°K, and large, positive room temperature Hall coefficients. As Mo concentration is increased the superconducting transition temperature increases, the normal resistivity decreases, and the temperature coefficient of resistivity changes from negative to positive. Extrapolation of the data to zero atomic percent Mo indicates that for a hypothetical pure bcc Ti, $\rho(300°K)\sim180\ \mu\Omega$ cm, $\rho(4.2°K)\sim205\ \mu\Omega$ cm, and $\rho(\sim2°K)=0$ (superconducting), in marked contrast to values for hcp Ti. As suggested by Coles,[1] localized electronic spin states in bcc Ti might account for the resistive anomalies via a spin-disorder scattering mechanism. The presence of intense localized lattice strains in these alloys is implied by the unusually high fields required to restore normal resistance (an 18.3 atomic percent Mo specimen exhibited zero resistance at 1.2°K in a field of 30 kilogauss for a measuring current density of 34 amp/cm^2), and the broad zero field bulk transition, covering a range of 0.6°K as indicated by the calorimetric measurements.

* This work was supported by the U. S. Atomic Energy Commission.
[1] B. R. Coles, *Advances in Physics* (Taylor and Francis, Ltd., London, 1958), Vol. 7, p. 40.

N4. Experimental Determination of the Small Absorption Values in Semiconductor Films. W. F. KOEHLER, *U. S. Naval Ordnance Test Station.*—A precision method of obtaining the small absorption values beyond the absorption edge of a semiconductor will be reported. When a slightly absorbing film is evaporated onto a highly reflecting substrate, the values at the minima of the oscillatory reflection function are very sensitive to small amounts of absorption. The method consists of matching a precisely measured minimum reflection coefficient with one of a group calculated using various values of k, the imaginary part of the complex index of refraction. The value of k which yields the best match is used to calculate the absorption coefficient α according to $\alpha=4\pi k/\lambda$. The method will be demonstrated by reflection measurements made on amorphous selenium which was evaporated onto an aluminized optical flat. One possible interpretation of the results yields not only the usual optical energy gap but also an estimate of the width of the conduction band.

N5. Galvanomagnetic and Thermomagnetic Effects in PbTe. H. N. LEIFER, M. R. ELLETT, K. F. CUFF, AND R. S. KROGSTAD, *Lockheed Research Laboratories.*—In an attempt to understand the scattering mechanisms in PbTe and similar semiconductors, magnetoresistance, thermomagnetic, resistivity, Hall, and thermoelectric measurements have been carried out in the temperature range of 300°K to liquid helium. The magnetoresistance data is in qualitative agreement with previous work[1] and indicates energy ellipsoids oriented in the (111) direction. The magnitude of the anisotropy parameter K and the energy dependence of the scattering relaxation time have been determined over the temperature range. Thermomagnetic measurements (transverse and longitudinal Nernst-Ettinghausen effect) have also been carried out in the indicated temperature range. The energy dependence of the scattering relaxation time can be inferred directly from these measurements and agrees generally with that obtained by the magnetoresistance measurements. These results will be interpreted in the light of the multivalley structure and the temperature dependence of mobility.

[1] R. S. Allgaier, Phys. Rev. 112, 828 (1958).

N6. Thermal Power Measurements by Means of Pyroelectric Ceramic Transducers. T. A. PERLS AND B. L. MATTES, *Lockheed Missiles and Space Division.*—Following a previous investigation of primary pyroelectricity in barium titanate ceramics,[1] large disks of $BaTiO_3$ and of lead zirconate-titanate (PZT) were used in the field to measure total thermal heat rate. The current generated is proportional to the net heat energy absorbed per unit time, and a record proportional to thermal power is thus readily obtained with a recording galvanometer, the characteristics of which determine the over-all frequency response. The spectral response of the material is intrinsically uniform, and the effective spectral response is determined by the emissivity of the black coating used. For constant heat input the net power absorbed decreases (by radiation) as the transducer is heated but, simultaneously, the pyroelectric sensitivity increases. The output current thus remains very nearly proportional to thermal power for an appreciable length of time and over a wide range of heat input rates. For rates in excess of 2 w/cm^2, improved performance is obtained with the PZT materials which have a Curie point above 300°C. For $Ba_{0.96}Pb_{0.04}TiO_3$ and PZT disks $\frac{1}{8}$ in. thick, the current sensitivity was found to be $0.026\pm0.002\ \mu$a/w,

and 0.033 ± 0.002 μa/w, respectively, by comparison with a copper-disk-and-thermocouple calorimeter.

[1] Perls, Diesel, and Dobrov, J. Appl. Phys. **29**, 1297 (1958).

N7. Dependence of Equilibrium Properties on the Shapes of Particle Interaction Potentials. I. Effect of the Repulsive Branch. LESTER HAAR, *Convair.*—Several different forms of short-range potential functions frequently employed for interacting atomic particles are examined. We are particularly interested in the dependence of the thermodynamic properties of dilute systems on the shape of the positive potential energy regions, and calculations for different potentials are compared. It is shown that up to temperatures of the order of the particle dissociation energies the thermodynamic properties are rather insensitive to the positive potential energy region, and, in fact, a rigid sphere approximation for this part of the interaction potential would not result in errors larger than a few percent in calculated second virial coefficients.

N8. Intensities in the Optical Absorption of Cuprous Oxide.* P. W. BAUMEISTER AND F. A. JENKINS, *University of California, Berkeley.*—The absorption of thin polycrystalline slabs of Cu_2O at 295°, 77°, and 4.2°K has been measured with a single-beam recording grating spectrometer. At 4.2° absorption begins to rise at wave number $\sigma = 16\,510$ cm^{-1}. Until about 16 900 cm^{-1} the absorption coefficient α, relative to its value below 16 510, is closely represented by $4.8\ (\sigma - 16\,510)^{\frac{1}{2}}$ cm^{-1}. At still higher frequencies α rises more rapidly, reaching the value 276 cm^{-1} at the peak of the $K=2$ line of the yellow series of exciton lines. After the indicated background correction is applied, the ratio of the integrated absorption of the $K=3$ and $K=2$ lines is found to be 0.35. This ratio, as well as the square root frequency dependence of the continuous absorption, are in satisfactory accord with the theory of Elliott.[1] This agreement, and the absence of the line $K=1$, indicate that indirect transitions to exciton levels are involved. At 77°K, the continuous absorption shows an additional component, so that $\alpha = \alpha_1 + \alpha_2$, with $\alpha_1 \sim (\sigma - 16\,200)^{\frac{1}{2}}$ and $\alpha_2 \sim (\sigma - 16\,430)^{\frac{1}{2}}$. The indicated phonon temperature of 150°K agrees with the ratio of α_2 to α_1.

* Research supported by the National Science Foundation.

[1] R. J. Elliott, Phys. Rev. **108**, 1384 (1957).

FRIDAY AFTERNOON AT 2:00

George 226

(J. R. PELLAM presiding)

Magnetohydrodynamics

O1. Thermodynamic Properties of Fluid Flow across Magnetic Field I.* K. P. CHOPRA, *University of Southern California* (introduced by H. T. Yang).—This paper deals with the study of the various thermodynamic quantities like internal energy, enthalpy, entropy, etc., involved in the investigation of the flow of a conducting fluid in the presence of a uniform transverse magnetic field. The analogs of Rayleigh and Fanno lines readily follow from the basic equations. It is shown that in the presence of a transverse magnetic field, the internal energy and enthalpy of an electrically conducting fluid, obeying perfect gas equation, depend (unlike in ordinary fluid-flow thermodynamics) on its density and the strength of the magnetic field. The entropy and the specific heat at constant volume do not seem to be affected by the presence of the magnetic field. The behavior of specific heat at constant pressure depends on which of the gas and the total pressure is kept constant. A transverse magnetic field reduces the specific heat at constant gas pressure and the corresponding adiabatic constant by a factor proportional to the ratio of the magnetic pressure to the gas pressure. However, if the total (gas plus magnetic) pressure is kept constant, the magnetic field has no effect. Lastly, the effect of the magnetic field on velocity of sound and the Mach number is discussed. In the limiting cases of weak and strong magnetic fields, the velocity of sound reduces to the ordinary sonic speed and the Alfvén speed respectively.

* Supported in part by the U. S. Air Force Office of Scientific Research.

O2. Propagation of a Plane Normal Shock Wave in a Gas Mixture of Two Kinds of Charged Particles in the Presence of a Transverse Magnetic Field.* INDERJIT SINGH, *Oil and Natural Gas Commission, Government of India,* AND K. P. CHOPRA, *University of Southern California* (introduced by H. T. Yang).—The propagation of a shock wave in a gas mixture sets up diffusion and causes a change in the composition of the fluid. The effect of diffusion on the propagation properties of a shock wave in the presence of a transverse magnetic field forms the subject matter of this paper. Transverse (induced by magnetic field) and thermal diffusions have been ignored for simplicity. Expressions for the composition parameter, and pressure, density, and velocity ratios are obtained. Chief conclusion is that the presence of a transverse magnetic field narrows down the range of values for the density ratio. The analysis is suggestive of the contribution of diffusion to the structure of the shock front. However this conclusion is not established to finality.

* Supported in part by the U. S. Air Force Office of Scientific Research

O3. Depletion of Slow Electrons in Plasma Heating by Energetic Ions. C. B. SHAW, JR., *Hughes Aircraft Company.*—Energetic ions passing through a plasma lose energy by Coulomb interaction with those plasma electrons whose speed is less than that of the incident ions.[1] Comparison of the ion-electron and electron-electron relaxation times, as usually calculated for small deviations from the Maxwell distribution, indicates that inter-electron collisions will distribute the incremental energy acquired by the slow electrons among all plasma electrons so rapidly that the electron velocity distribution will remain essentially Maxwellian while the plasma temperature increases.[2] However, W. I. Linlor has suggested, and given various arguments to indicate,[3] that this need not be the case for an ion flux sufficiently great in comparison with electron density. An investigation has therefore been made of the conditions under which an appreciable depletion of the slow-electron population would occur. No restriction to small perturbations of the Maxwell distribution was imposed in this analysis.

[1] S. Chandrasekhar, Astrophys. J. **97**, 255 (1943); L. Spitzer, Jr., *Physics of Fully Ionized Gases* (Interscience Publishers, Inc., New York, 1956).
[2] L. Spitzer, reference 1, Chap. 5.
[3] W. I. Linlor (private communication).

O4. Piezoelectric Measurements in Fusion Research.* MARTIN O. STERN, *General Atomic.*†—In high-density high-current discharges in connection with our thermonuclear research program it is desirable to measure the material pressure directly. How a piezoelectric device can be constructed and calibrated to accomplish this will be described. Attempts to measure material pressure directly with piezoelectric devices have been made in Russia,[1] but methods and results have not been reported in complete detail. Our device consists of a fused quartz acoustic line open at both ends. One end is immersed in the plasma. The line is interrupted at some intermediate point for insertion of a thin piezoelectric wafer cut for thickness vibration. The ends of the acoustic line adjoining the wafer are coated with thin metallic layers, before being glued to the wafer. The signal from the piezoelectric is transmitted in coaxial geometry from these layers to an oscilloscope. For calibration a thin metal disk is temporarily attached to the input end of the acoustic line. This end is inserted in a coil through which a high current of short duration is discharged, causing a pressure pulse to travel down the line through the piezoelectric.

* This work was done under a contract between General Atomic and the Texas Atomic Energy Research Foundation.
† John Jay Hopkins Laboratory for Pure and Applied Science, General Atomic Division of General Dynamics Corporation, San Diego, California.
[1] A. M. Andrianov *et al.*, *Proceedings of the Second International Conference on the Peaceful Uses of Atomic Energy* (United Nations, Geneva, 1958), Vol. 31, p. 348, P/2301 USSR.

O5. Observations on a Shock-Heated Deuterium Plasma Compressed by an Axial Magnetic Field.* W. E. QUINN, E. M. LITTLE, G. A. SAWYER, AND T. F. STRATTON, *Los Alamos Scientific Laboratory.*—The Scylla plasma experiment[1,2] employs a rapidly rising magnetic field in a cylindrical mirror geometry to heat a deuterium plasma. Emission of neutrons and x-rays has been observed[1-3] and is suggestive of an appreciable plasma temperature. Streak camera photographs which show the space and time evolution of the electrodeless discharge have been obtained. Magnetic probe measurements in the plasma region were made. The neutron yield was severely reduced by the perturbing effect of the probe. The magnitude and time distribution of the neutron emission will be compared for magnetic compression fields with and without mirror geometry. In addition a new Scylla device which employs the same 100-kv capacitor bank[3] as the initial Scylla experiment but has an additional 20 kv, 140 kilojoule capacitor bank to extend the magnitude and time scale of the magnetic compression will be discussed.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] Elmore, Little, and Quinn, Phys. Rev. Letters **1**, 32 (1958).
[2] Boyer, Elmore, Little, and Quinn, *Proceedings of the Second United Nations International Conference on Peaceful Uses of Atomic Energy* (United Nations, Geneva, 1958), Vol. 32, p. 337.
[3] Boyer, Little, Quinn, Sawyer, and Stratton, Phys. Rev. Letters **2**, 518 (1959).

O6. Trapped DDT Waves in Card-Cap Method. R. B. CLAY, M. A. COOK, R. T. KEYES, AND O. K. SHUPE, *University of Utah* (introduced by Thomas J. Parmley).—Detonations reform via the DDT (deflagration to detonation transition) through barriers (SPHF plates) from donor charges in time τ and at distance S_2 into the receptor charge, where $S_2/\tau = C$ —acoustic velocity.[1] But when $L_r < S_2$ (L_r = receptor length) no DDT occurs.[2] Here, however, the discovery was made that, with metals on the ends of receptors of length $S_2/2 < L_r < S_2$ to reflect the DDT wave, the DDT occurred at the time τ characteristic only of the donor-SPHF system and at distance $y = 2L_r - S_2$ from the SPHF plate. Using $L_r < S_2/2$ and a metal plate on the end of the receptor for wave reflection no DDT occurred with glass SPHF's. But DDT's occurred with glass-backed for reflection by metal-SPHF's again at τ determined by the donor-SPHF system, and at $y = S_2 - 2L_r$. In all cases the trapped DDT wave thus traveled in total the distance $S_2 = C\tau$ before initiating the DDT. Finally, when donor-SPHF systems were used on each end of receptors of length $S_2 < L_r < 2S_2$ two DDT's were observed each fulfilling the condition $S_2/\tau = C$ and each *knowing its own donor*! Photographs of these phenomena are presented and discussed in terms of the two theories extant of the card-gap test.

[1] Cook, Pack, Cosner, and Gey, "The instrumented card-cap test," J. Appl. Phys. (to be published).
[2] Cook, Pack, and Gey, Seventh Symposium (International) on Combustion (1959), p. 828, Fig. 9.

O7. Metallic Catalysts for Detonation-Generated Plasmas. M. A. COOK, D. H. PACK, AND W. S. MCEWAN, *University of Utah.*—Detonations generate high density plasmas by chemionization in the reaction zone[1] and these plasmas, ejected into surrounding gaseous media, exhibit phenomenal stability. Their formation has been studied in the DDT (deflagration to detonation transition) using the "SPHF-plate" method, instrumented by ultra-high speed, color photographic, and electrical probe methods.[1-3] In the SPHF-plate method one observes the various phenomena associated with the DDT in a receptor charge separated from the donor by the SPHF plate. Here glass SPHF plates were employed and the influence of thin metal foils on the receptor surface of the glass studied. The time τ required for the DDT and the distance S_2 into the receptor charge where it occurred (S_2/τ = acoustic velocity in the receptor[1,4]) were found to be remarkably influenced by the metal-foil catalysts, τ and S_2 being reduced sometimes to less than 0.2 their values in the corresponding uncatalyzed system. This paper describes experimental results of the metallic catalysis of these plasmas and presents an interpretation in terms of "quasi-metallic" model.[5]

[1] M. A. Cook, *The Science of High Explosives* (Reinhold Publishing Corporation, New York, 1958).
[2] Cook, Pack, and Gey, Proc. Roy. Soc. (London) **A246**, 281 (1958).
[3] Cook, Pack, and Gey, Seventh Symposium (International) on Combustion (1959), pp. 820–836.
[4] Cook, Pack, Cosner, and Gey, "The instrumented card-gap test," J. Appl. Phys. (to be published).
[5] M. A. Cook and W. S. McEwan, J. Appl. Phys. **26**, 1612 (1958).

O8. Ion Plasma Oscillations Induced by a Supersonic Charge. S. RAND, *Convair.*—A particle treatment is applied to a study of the ion plasma oscillations behind a charged body moving supersonically through a low-density plasma. For the case of a body whose dimensions are considerably smaller than a Debye length, a formula is obtained such that with two alternate approximations, the fluid dynamics results, with an effective specific heat ratio of 2, are found in one case, and the results of the linearized Boltzmann equation, without collisions and with Landau damping absent, are obtained in the other case. This latter omission results from the neglect of the effect of ions moving with the phase velocity of the potential wave. For the case of a disk whose radial dimensions are much larger than a Debye length, the ion and electron densities are increased above their ambient values. Formulae for the electrohydrodynamic drag on a wire an on a large disk are obtained.

O9. Ionization World Lines in Gaseous Predetonation.* GEORGE J. HECHT,† A. J. LADERMAN, R. A. STERN, AND A. F. OPPENHEIM, *University of California, Berkeley* (introduced by Roger Wallace).—The techniques and apparatus required to extend the use of "pin or gap" type ionization detectors to yield reliable timing signals throughout the predetonation zone in detonation tube research with gaseous mixtures is fully described. Accurate timing signals in this zone provide direct data for a recent analysis by Oppenheim and Stern[1] of the events leading up to detonation. Their analysis rests solely on the space-time history or "world lines" of flame fronts, shocks, rarefactions, and contact discontinuities. A consideration of the mechanisms of ionization in the predetonation zone is presented and it is shown that flame induced ionization can be distinguished unambiguously from that due to shocks on the basis of pulse amplitude of the signals appearing at the detectors. Design and construction of the probes, amplifier-

thyratron timing channels, and operational requirement are presented. Precision of the apparatus is shown to be better than 2% throughout the entire predetonation zone. Experiments with H_2-O_2 mixtures are described and the results shown to yield the flame world line.

* This research supported by the U. S. Air Force, through the Air Force Office of Scientific Research of the Air Research and Development Command.
† Present address: Shell Development Company, Emeryville, California.
[1] A. K. Oppenheim and R. A. Stern, Combustion Symposium (1959).

O10. Experiments on Reverse-B_z Pinch Stabilization. L. C. BURKHARDT AND R. H. LOVBERG, *Los Alamos Scientific Laboratory.*—An attempt has been made to give complete hydromagnetic stability to a linear pinched gas discharge by applying a longitudinal magnetic field external to the discharge current, and directed oppositely to the stabilizing B_θ field in the discharge core.[1,2] For each set of field parameters used, the pinch was mapped with magnetic probes to determine if the Suydam necessity criterion[1] had been met. For deuterium pinches, it has proved impossible, within the machine capabilities, to satisfy the criterion, since the increase in shear of the fields, which has a stabilizing influence, is accompanied by an increased peaking of the plasma pressure distribution at the current shell radius, and the negative pressure gradient at the exterior of the pinch is increased, thus removing stability. An argon pinch of the same mass density has been made to satisfy the necessity criterion, however. This is possible through reduction in plasma pressure by radiation losses from the argon. Nevertheless, a fluttering of the plasma shell persists.

[1] B. Suydam, *Proceedings of the Second International Conference on the Peaceful Uses of Atomic Energy* (United Nations, Geneva, 1958), A/Conf. 15/P/1364.
[2] M. N. Rosenbluth, reference 1, A/Conf. 15/P/1074.

O11. Charge Excitation of Plasma Motion in a Magnetic Field.* R. PAPPERT, *Convair.*—The wake of a charged body traversing a low density plasma of vanishing ion temperature, in a constant external magnetic field, is investigated by combining the developments of Kraus and Watson[1] and Bernstein.[2] The speed of the exciting charge is taken to be less than the rms thermal speed of the electrons and its dimensions are assumed small relative to the electron Debye length of the plasma. The magnetic field is taken along the direction of motion of the exciting charge. One of the effects of the magnetic field is the production of oscillations of both the charge density and the potential. Over some regions of space the frequency of these oscillations is approximately equal to the ion cyclotron frequency.

* This work was supported by the Office of Naval Research.
[1] L. Kraus and K. M. Watson, "Plasma motions induced by satellites in the inosphere," Convair Report ZPh-016 (March, 1958).
[2] I. Bernstein, Phys. Rev. **109**, 10 (1958).

O12. Theory of the Stagnation-Point Langmuir Probe.* L. TALBOT, *University of California, Berkeley.*—A theory is developed for a Langmuir-type probe consisting of a collecting electrode placed at the stagnation point of a blunt body immersed in a supersonic, partially ionized stream. It is shown that under certain conditions, the stagnation-point boundary layer equations and the probe sheath equations can be solved together to yield potential *versus* current relationships which permit the free stream ion and electron densities and temperatures to be measured by such a probe. It is also shown that the stagnation-point heat transfer will vary with probe potential, thus providing additional information useful in plasma jet diagnostics.

* This work was supported by the U. S. Air Force Office of Scientific Research.

FRIDAY EVENING AT 8:00

Princess Kaiulani Hotel

Banquet of the American Physical Society

After-Dinner Speech

The Scientist as Administrator. CHANCELLOR G. T. SEABORG, *University of California, Berkeley.*

SATURDAY MORNING AT 9:30

Crawford 105

(F. S. JOHNSON presiding)

Invited Papers

P1. Solar Activity and Its Terrestrial Effects. J. B. ZIRKER, *Sacramento Peak Observatory, New Mexico.* (30 min.)

P2. Whistlers and the Outer Ionosphere. ROBERT A. HELLIWELL, *Stanford University.* (30 min.)

P3. Adiabatic Motion of Charged Particles, Theoretical and Experimental. THEODORE G. NORTHROP, *University of California, Livermore.* (30 min.)

P4. Hydromagnetic Theory of Magnetic Storms. ALEXANDER J. DESSLER, *Lockheed Missiles and Space Division.* (30 min.)

P5. Cosmic-Ray Neutrons and the Van Allen Radiation Belt. WILMOT N. HESS, *University of California, Berkeley.* (30 min.)

SATURDAY MORNING AT 9:30

Crawford 103

(I. TALMI presiding)

Low-Energy Nuclear Physics

Q1. Linear Relation for the Binding Energy of Nuclei up to Mass Number 60. LEONARD S. LEVITT, *Stevens Institute of Technology.*—It is unrealistic to say that the binding energy per nucleon for the deuteron is 1.11 Mev, since the neutron and proton are each bound one to the other by 2.22 Mev. One should, instead, calculate the average binding energy per *added* nucleon, assuming one original nucleon for each nuclear species. On the basis of the plot of A *vs* $E_B/(A-1)$ instead of E_B/A, a new binding energy curve is constructed which clearly illustrates the great stability of He^4 by its unique position above the *entire* curve (9.43 Mev/added nucleon, compared to 8.95 for Fe^{56}). Except for He^4, then, the curve for $1<A<60$ is a rectangular hyperbola represented by the equation $E_B=B(A-1)^2/(a+A)$, where a and B are empirical constants. This expression can be cast into linear form by rewriting it as $(A-1)^2/E_B=a/B+A/B$. Thus the plot of $(A-1)^2/E_B$ *vs* A is nearly a perfect straight line with slope $1/B$, and intercept a/B. Evaluation of the constants gives $a=1.41$ and $B=9.41$ Mev, the same value as $E_B/(A-1)$ for He^4. The binding energies of all other nuclides up to $A=60$ are therefore given by $E_B=E_{B(He)}(A-1)^2/(3)(1.41+A)=9.41(A-1)^2/(A+1.41)$.

Q2. Least-Squares Analyses of the Standard and Generalized Semiempirical Mass Laws. FORREST MOZER, *Lockheed Missiles and Space Division and California Institute of Technology.*—Least-squares analyses have been performed on a set of atomic masses using standard and generalized semiempirical mass laws. Presumably because of errors in the assumed form of the standard mass law, its least-squares coefficients can be determined at best to an accuracy of about 10%, and masses are predicted with an uncertainty of several Mev/c^2. The standard mass law has been generalized by addition of two shell effect terms. Although the least-squares fitting of the generalized mass law is better than for the standard mass law, it is still not possible to predict quantitatively atomic masses to an accuracy better than a few Mev/c^2. The nuclear deformations and the well depth of the nuclear interaction obtained from the additional mass law terms are in reasonable agreement with more accurate determinations by other methods. A similar statement applies to the nuclear radius constant as obtained from the least squares coefficient of the Coulomb energy term. A study has also been made of the effects of additional terms proportional to the absolute value of the isotopic spin, exchange and surface corrections to the Coulomb energy, and the surface correction to the normal isotopic term.

Q3. Energy Levels in Ca^{42}. R. D. SHARP, L. F. CHASE, JR., AND R. M. FRIEDMAN, *Lockheed Missiles and Space Division.*—Thin targets of potassium iodide enriched in K^{41} to 86.8% have been bombarded with protons in the energy range from 2.3 to 3.5 Mev, and the excitation functions of the two most prominent gamma rays have been measured. Coincidence measurements indicate that these gamma rays of 1.00 Mev and 2.16 Mev originate from the $K^{41}(p,p'\gamma)$ and $K^{41}(p,\alpha\gamma)$ reactions, respectively. Both excitation functions show many resonances, most of which are only partially resolved, corresponding to excited states in the nucleus Ca^{42} in the range of excitation 12.6 to 13.8 Mev. The energies and 90° peak yields of approximately 50 of these states will be presented, as well as estimates of the partial width ratios and the level density in this region of excitation.

Q4. $S^{34}(p,\gamma)Cl^{35}$ Reactions.* J. A. MOORE, J. L. KRUMWIEDE, AND E. A. MILNE, *United States Naval Postgraduate School.*—The resonances for proton absorption by S^{34} between E_p of 800 and 1950 kev were investigated by bombarding targets of CdS with a proton beam from a Van de Graaff accelerator. Both S^{34}-enriched and natural isotopic targets were prepared by vacuum plating CdS upon a tantalum base. The gamma yield from the bombardment was observed by a 2-in.×2-in. well-type scintillation crystal, placed over the target. By comparing yields from S^{34}-enriched and natural isotopic targets, the resonances due to $S^{34}(p,\gamma)Cl^{35}$ were determined. The observed $S^{34}(p,\gamma)Cl^{35}$ resonances in kev, and relative amplitudes were 1015, 1.5; 1206, 13.5; 1523, 4.5. The low resonances at 1370, 1610, 1697, 1810, and 1860 kev, reported by Hanscome and Malich,[1] may have appeared, but they were not sufficiently resolved for conclusive confirmation.

* Supported in part by the Office of Naval Research.

[1] T. D. Hanscome and C. W. Malich, Phys. Rev. **82**, 304(A) (1951).

Q5. $S^{33}(p,\gamma)Cl^{34}$ Reactions.* A. H. GAEHLER, A. L. KNIPP, JR., AND E. A. MILNE, *United States Naval Postgraduate School.*—The $S^{33}(p,\gamma)Cl^{34}$ reaction has been studied in the energy range of 1100 to 1550 kev by bombarding CdS targets enriched to 22% S^{33} with a proton beam from a Van de Graaff accelerator. The gamma-ray yield, obtained by means of a 2 in.×2 in. well-type scintillation counter, was compared to the yield from natural isotopic targets. The resonances attributed to S^{33} occurred at 1152 kev, 1211 kev, 1262 kev, 1434 kev, 1456 kev, and 1525 kev.

* Supported in part by the Office of Naval Research.

Q6. Complex Positron Spectrum of the 16.1-Day Isomer of Rhodium-99.* C. W. TOWNLEY, J. D. KURBATOV, AND M. H. KURBATOV, *The Ohio State University.*—The positron spectrum was investigated with a thick lens spectrometer and a crystal scintillation coincidence spectrometer. A carrier free chemically purified sample of Rh^{99} was obtained after proton activation[1] of 86.9% enriched Ru^{99}. The Kurie plot of noncoincidence data gave a 1.03±0.01 Mev u.e.l. By subtraction additional positron spectra were obtained with u.e.l. of 0.71±0.01, 0.59±0.01, 0.42±0.02 and, in the low-energy region, a less certain spectrum of u.e.l., 0.31 Mev. Gamma-beta coincidences yielded the following results: coincidences with 90-kev gamma rays gave a complex spectrum which was resolved into three simple spectra; 0.715, 0.590, and 0.44±0.02 Mev u.e.l. Coincidences with the 349-kev gamma ray gave two spectra; 0.59 and 0.41±0.02 Mev u.e.l. The 1.03-Mev u.e.l. spectrum was not observed in coincidence with the 90-kev gamma rays or any other gamma rays. This suggests that it decays to the ground state of Ru^{99}. This would place the ground state of the 16.1-day isomer of Rh^{99} at 2.05 Mev above the ground state of Ru^{99}.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] Activation done in the cyclotron of the University of Washington, Seattle. The cooperation of G. W. Farwell and T. J. Morgan is gratefully acknowledged.

Q7. Radiative Capture of Deuterons by H^3.* J. H. COON AND R. W. DAVIS, *Los Alamos Scientific Laboratory.*—The emission of 16.7-Mev gamma rays has been observed from thick targets of tritium bombarded by 470-kev deuterons. Presumably the gamma rays are produced by the de-excitation

of He^6 from a known $J=3/2^+$ state. Preliminary data indicate the ratio of the yield of the gamma rays to that of the neutrons from $H^3(d,n)He^4$ is about 2×10^{-5} at both 0° and 90°. This yield is the same order of magnitude as that observed[1] from the mirror reaction $He^3(d,\gamma)Li^5$. A rough estimate reported by Sawyer and Burkhardt[2] of the yield ratio to be expected from $H^3(d,\gamma)He^5$ and $H^3(d,n)He^4$ is $\sim2\times10^{-4}$, ten times the observed yield presently reported. It is hoped that the experimental methods developed for this measurement will make possible an investigation of unknown features of the level structure of He^5 and Li^5.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] Blair, Hintz, and Van Patter, Phys. Rev. **96**, 1023 (1954).
[2] G. A. Sawyer and L. C. Burkhardt, Phys. Rev. **98**, 1305 (1955).

Q8. New Level at 6.3 kev in Ta^{181}.* ARTHUR H. MUIR AND FELIX H. BOEHM, *California Institute of Technology.*—A new level at 6.3 kev has been found in the Ta^{181} levels which are populated by the electron capture decay[1] of W^{181} and by the beta decay[2,3] of Hf^{181}. Data taken with a low-energy 180° β-ray spectrometer using a W^{181} source show conversion lines that are interpreted as the M-shell conversion of a 6.3-kev transition. The corresponding γ ray has been observed with an argon proportional counter. Intensities and conversion coefficients will be reported. A coincidence experiment has shown that previously reported[2] 476.0- and 482.0-kev transitions in Ta^{181} from the Hf^{181} decay are not in cascade as had been speculated. The most plausible alternative is that the 476-kev transition proceeds from the 482-kev level to a level at 6 kev. Direct evidence of a 6.3-kev transition of extremely weak intensity in the Hf^{181} decay is also found.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] P. Debrunner *et al.*, Helv. Phys. Acta **29**, 235, 432, 463 (1956) and Bisi, Terrani, and Zappa, Nuovo cimento **1**, 651 (1955).
[2] F. Boehm and P. Marmier, Phys. Rev. **103**, 342 (1956).
[3] E. S. Snyder and S. Frankel, Phys. Rev. **106**, 755 (1957).

Q9. Experimental Lifetimes of Positrons in Metals. G. JONES, *University of British Columbia.*—Positron lifetimes in a variety of metals have been measured using a time sorter[1] of 10^{-11}-sec stability over the course of a day. The absolute lifetime of positrons in aluminum was obtained by two methods. Comparison to prompt gamma rays from Co^{60}: by employing this standard technique, estimates of the first two moments of the annihilation distribution functions were obtained. An analysis based on simple exponential decay yielded a value for the mean life of $(2.40\pm0.15)\ 10^{-10}$ seconds. Comparison to prompt annihilation gamma rays from positron decay: In this method, the side channel energy selectors of both counters are set on a narrow band of energy near the peak of the Compton distribution for annihilation gamma rays. In this way, a value for the variance of the annihilation distribution function is obtained, corresponding to a mean lifetime which agrees within experimental error with the value quoted above. Lifetimes in the following metals were obtained by comparison with aluminum, for which the value is taken as 2.40×10^{-10} sec. Co(2.10), Cu(2.34), Au(2.52), Fe(2.07), Pb(2.40), Ag(2.30), Sn(2.54), mica(3.17), W(2.01) (±0.1, in units of 10^{-10} sec).

[1] J. B. Warren and G. Jones, Bull. Am. Phys. Soc. Ser. II, **3**, 327 (1958).

Q10. Gamma Rays from $SI^{29}(p\gamma)$. J. J. SINGH, *University of Kansas.*—A study of the reaction $Si^{29}(p,\gamma)$ has been made at a number of resonances in the proton energy range of 400 kev–1100 kev. Pulse-height spectra were investigated at all the prominent resonances. Experimental evidence proving the existence of two close-lying states at 685 kev and 708 kev is discussed. Weak ground-state transitions were observed only at 414-kev, 696-kev, and 956-kev resonances. At these as well as other resonances, various cascades leading through well-established levels in P^{30} have been identified. Attempts to establish the rotational character of some of the states will be discussed.

Q11. Equilibrium Electronic Charge Distributions for Heavy Ions.* HARRY H. HECKMAN, EDWARD L. HUBBARD, BETTY L. PERKINS, AND WILLIAM G. SIMON, *University of California, Berkeley.*—We are measuring the equilibrium distributions of electronic charge states of C^{12}, O^{16}, and Ne^{20} ions that have traversed thin foils of Zapon at energies between 2.5 and 10 Mev/nucleon. The 10-Mev/nucleon beam of the hilac is degraded, as necessary, by aluminum foils, collimated, and magnetically analyzed. The final collimator is a slit 0.040 in. (adjustable) by $\frac{3}{8}$ in., placed about 18 ft from the analyzing magnet. The Zapon foil is positioned immediately behind this slit. After penetrating the foil, the beam (originally in a unique charge state with a spread in momentum $<1\%$) is reanalyzed into separate charge states in a 22-in. magnetic spectrometer. The beam enters and leaves the magnet radially. To detect the particles, we place normal to the beam and along the circumference of the magnet a 1.5-in.-wide strip of acetate-backed 200-μ C.2 emulsion. Estimates of the total number of ions in each charge group are made by counting the vertical tracks under high magnification. The method permits measurements of relative intensities through five orders of magnitude to a statistical accuracy of a few percent. Preliminary results have been obtained for O^{16}, and the C^{12} and Ne^{20} data are now being taken. Zapon foils of 80 $\mu g/cm^2$ are used to produce the equilibrium distributions, although for O^{16} at 4.0 Mev/nucleon no detectable differences in the distributions are observed for thicknesses 20 $\mu g/cm^2$ and greater.

* Work done under the auspices of the U. S. Atomic Energy Commission.

SATURDAY MORNING AT 9:30

Crawford 209

(V. L. TELEGDI presiding)

Invited Paper

R1. Recent Studies of Cosmic-Ray Neutrons. SERGE A. KORFF, *New York University.* (30 min.)

High-Energy Nuclear Physics

R2. Polarization of Recoil Protons in π^0 Photoproduction.* V. Z. PETERSON, *California Institute of Technology,* AND J. FRIEDMAN AND H. KENDALL, *Stanford University.*—The polarization of the recoil protons from the reaction $\gamma+p\rightarrow p+\pi^0$ has been determined from the asymmetry in scattering of the protons within nuclear emulsion. The 650-Mev electron

beam of the Stanford linear accelerator produced bremsstrahlung in a 0.011-in. copper radiator prior to the liquid hydrogen target; the electron beam also traversed the hydrogen. The protons were momentum-analyzed by a 180° double-focusing magnetic spectrometer.[1] The momentum resolution was 3% at 540 Mev/c. Proton laboratory angles of 43.5° and 33.0° were chosen to investigate polarization produced by photons of 585 Mev and 450 Mev with photon energy resolution of about 20 Mev. The spread in angle of the protons entering the emulsion is ±1°. This makes it possible to measure the degree of polarization by the procedure of Feld and Maglic.[2] We have used their value for the analyzing power of emulsion; namely, 0.62 for scatters between 6° and 12°. The polarization at 450 Mev is low; later results on this and the 585 Mev value will be presented. Contamination by protons inelastically scattered by electrons should be less than 3%. The proton's magnetic moment is rotated by the 180° spectrometer so that it is again perpendicular to the direction of proton motion as it enters the emulsion.

* This work was supported in part by the U. S. Atomic Energy Commission.
[1] E. E. Chambers and R. Hofstadter, CERN Symposium 1956, Vol. 2.
[2] B. T. Feld and B. C. Maglic, Phys. Rev. Letters 1, 375 (1958).

R3. Complete Determination of Polarization for a High-Energy Deuteron Beam. JANICE BUTTON, *University of California, Berkeley.*—Measurements have been made, by double scattering, of all parameters necessary to describe completely the interaction of the deuteron with complex nuclei. Deuterons of 410 and 420 Mev were scattered from beryllium and carbon, respectively. Tensor components of polarization, which characterize the scattering of spin-one particles and which were unobservable at low energies, were determined to be appreciably different from zero. The usual vector spin polarization normal to the plane of scattering was found to reach a maximum of about 70%. The impulse approximation was employed to obtain estimates of deuteron cross section and polarization on the basis of nucleon scattering data.

R4. Strange-Particle Production in Antiproton Annihilation Events.* SULAMITH GOLDHABER, WILLIAM B. FOWLER, GERSON GOLDHABER, T. F. HOANG, WILSON M. POWELL, AND REIN SILBERBERG, *University of California, Berkeley.*—Antiproton interactions and annihilations at a $\bar{p}$ momentum of 1.1 Bev/c have been studied in the L. R. L. 30-in. propane chamber; 22 000 pictures were taken in an enriched $\bar{p}$ beam.[1] About 2500 $\bar{p}$ annihilation events were observed in the central region of the chamber. In about 130 annihilation stars, strange particles were produced that were observed to decay in the chamber. The strange-particle production has been measured by analyzing the charged decay modes of θ_1 mesons emitted in the annihilation. We deduced from these events the total number of strange particles produced. Corrections for absorption of θ mesons in the carbon nucleus have been made. To date, about 45 events with one θ_1 meson have been observed and 6 events with two θ_1 mesons. Comparing this number with strange-particle production from annihilation events at rest and at relatively low $\bar{p}$ energies,[2] we find an appreciable increase in the strange-particle production. The implication of these results on proposed statistical models will be discussed.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
[1] Alvarez, Eberhard, Good, Graziano, Ticho, and Wojcicki, Phys. Rev. Letters 2, 215 (1959).
[2] Chamberlain, Goldhaber, Jauneau, Kalogeropoulos, Segrè, and Silberberg, Phys. Rev. 113, 1615 (1959); and L. Agnew (Lawrence Radiation Laboratory) (private communication).

R5. Pion-Pion Correlations in Antiproton Annihilation Events.* GERSON GOLDHABER, WILLIAM B. FOWLER, SULAMITH GOLDHABER, T. F. HOANG, THEODORE E. KALOGEROPOULOS, AND WILSON M. POWELL, *University of California, Berkeley.*—Among 2500 antiproton annihilation events[1] we have analyzed about 400 "hydrogenlike" events with 4 and 6 charged pions, respectively. We find that the distributions of the angles (in c.m. of $\bar{p}$-nucleon system) between equally charged pions is strikingly different from the distribution of the angles between pions of opposite charge. We have expressed this effect in terms of the ratio γ of the number of pion pairs with angles greater than 90° to the number smaller than 90°. We find in the four charged-pion events γ_4(like) $=1.23\pm0.11$, γ_4(unlike) $=2.06\pm0.12$, and γ_4(like+unlike) $=1.72\pm0.08$; for the six pion events γ_6(like) $=1.06\pm0.15$, γ_6(unlike) $=1.91\pm0.23$, and γ_6(like+unlike) $=1.50\pm0.13$. The Lorentz invariant-phase-space (LIPS) model[2] predicts γ_4(LIPS) $=1.79$ and γ_6(LIPS) $=1.57$. The ratios γ(like) and and γ(unlike) differ significantly from each other and γ(like) also differs significantly from γ(LIPS). However, the ratios for γ(like+unlike) are in excellent agreement with γ(LIPS). The motivation for the study of these angular correlations was to see if pion-pion interactions could modify the results obtained from a simple statistical model.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
[1] Goldhaber, Fowler, Goldhaber, Hoang, Powell, and Silberberg, UCRL-8815 (previous abstract).
[2] P. P. Srivastava and G. Sudarshan, Nuclear Collisions, Phys. Rev. 110, 765 (1959) and T. E. Kalogeropoulos, "A study of the antiproton annihilation process in complex nuclei," Lawrence Radiation Laboratory Report UCRL-8677 (unpublished).

R6. Coupled Integral Equations for the Nucleon and Pion Electromagnetic Form Factors. M. BAKER AND F. ZACHARIASEN, *Stanford University.**—The dispersion relations for the nucleon isotopic vector form factors $F_N{}^V(q^2)$ and the pion form factor $F_\pi(q^2)$ which take into account contributions from both the 2π and $N\bar{N}$ states become a set of coupled integral equations for $F_N{}^V(q^2)$ and $F_\pi(q^2)$ if the four amplitudes $(\pi\pi|N\bar{N})$, $(\pi\pi|\pi\pi)$, $(N\bar{N}|\pi\pi)$, $(NN|N\bar{N})$ are assumed known. If these four amplitudes are replaced by their Born approximation values and spin and certain kinematic factors are neglected, the resulting set of coupled singular integral equations can be solved exactly. Comparison of these solutions for various values of the masses and coupling constants with the form factors obtained from the usual approximation of retaining only the lowest mass state (i.e., the 2π state) gives one a measure of the reliability of the usual hope that high mass states do not contribute much to dispersion integrals. It is also of interest that the above solutions were obtained from dispersion relations without a subtraction and satisfied the the necessary conditions that they vanish at ∞ and take on the value e at the origin for all values of the coupling parameters appearing in the equations.

* Supported in part by the U. S. Air Force through the Air Force Office of Scientific Research.

R7. Pion-Pion Scattering in the ϕ^4 Theory. F. ZACHARIASEN AND M. BAKER, *Stanford University.**—Pion-pion scattering has been calculated from the relativistic Hamiltonian $H=\lambda/4\phi^4$, using the determinantal method. The scattering amplitude for the individual partial waves is expressed as a ratio of two power series, and terms through λ^3 have been kept in each series. For $\lambda/4\pi=2.5$ the $T=1$, $J=1$ scattering amplitude goes through a broad resonance at a total center-of-mass energy of about $16\mu^2$. The calculation in the $T=1$, $J=1$ state yields directly a pion electromagnetic form factor which is needed for the evaluation of the two-pion contribution to the isotopic vector electromagnetic form factors, $F_1{}^V$ and $F_2{}^V$. For $\lambda/4\pi$ between 2.0 and 2.5 inclusion of this pion form factor results in considerable improvement in the fit of the shape of the theoretical $F_2{}^V(q^2)$ curve with the experimental data. The resulting isotopic vector moment $F_2{}^V(0)$ is about 0.8 $e/2M$ compared to the experimental value 1.85 $e/2M$.

* Supported in part by the U. S. Air Force through the Air Force Office of Scientific Research.

R8. Cosmic-Ray Neutron Energy Spectrum above 40 000 ft.* ROGER WALLACE, WILMOT N. HESS, H. WADE PATTERSON, AND EDWARD L. CHUPP.† *University of California, Berkeley.*—The neutron spectrum in equilibrium with the atmosphere, measured from thermal energies to about 1 Bev, from sea level to 40 000 ft,[1] at 44° north magnetic latitude has been extended through the transition region from a pressure altitude of 200 g/cm² to ∞ as a by-product of an albedo calculation.[2] It is found, as would be expected, that the lower energy end of the spectrum is depressed as the altitude increases and the nonequilibrium region is reached. Thus the maximum counting rate, or achievement of equilibrium for any particular neutron energy, occurs at lower altitudes as this energy becomes lower. Above the atmosphere the albedo spectrum[2] prevails with the intensity decreasing roughly as $1/r^2$. In the exosphere gravitational effects cause a further depletion below 0.065 ev. The resulting spectra complete the gap between the experimentally measured spectra below 40 000 ft and the neutron albedo spectrum used by Hess[2] to calculate the resulting proton and electron injection into the lower Van Allen layer.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
† Present address: Pilotless Aircraft Division, Boeing Aircraft Company, Seattle, Washington.
[1] Hess, Patterson, Wallace, and Chupp, "Cosmic-ray neutron energy spectrum" (submitted to Phys. Rev.).
[2] Wilmot N. Hess, Bull. Am. Phys. Soc. Ser. II, **4**, 365 (1959).

R9. Effect of a Pion-Pion Scattering Resonance on Nucleon Structure.* WILLIAM R. FRAZER AND JOSE R. FULCO.† *University of California, Berkeley.*—We have found that the existence of a resonance of suitable position and width in the $J=1$, $I=1$ state of the pion-pion system can bring the disposition-theoretical calculation of nucleon electromagnetic structure into agreement with experiment.[1] The calculation of the isotopic vector part of the nucleon form factors involves in first approximation the pion form factor and the matrix element for the production by two pions of a nucleon-antinucleon pair. For the pion form factor we used a semiphenomenological solution based on the work of Chew and Mandelstam[2] and involving two parameters related to the position and width of a reasonance. For the $\pi\pi \to N\bar{N}$ amplitude we found an approximate solution of the partial-wave dispersion relation derived from the Mandelstam representation.[3] Numerical results for the position and width of the resonance will be presented.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
† Visitor from the Argentine Army.
[1] W. R. Frazer and J. R. Fulco, Phys. Rev. Letters **2**, 365 (1959).
[2] G. F. Chew and S. Mandelstam, "Theory of the low-energy pion-pion interaction," UCRL-8728 (April, 1959).
[3] Stanley Mandelstam, Phys. Rev. **112**, 1344 (1958).

R10. High-Velocity Range and Energy-Loss Measurements.* STEN VON FRIESSEN† AND WALTER H. BARKAS. *University of California, Berkeley.*—An experiment to measure the relative stopping powers of Al, Cu, Pb, U, and emulsion in the proton energy intervals 750 to 600 Mev, 600 to 450 Mev, 450 to 300 Mev, and 750 to 0 Mev has been carried out. A "good geometry" beam was used so as to eliminate scattering corrections, and at the high particle energies chosen the shell corrections are small. When such corrections calculated by Walske[1] are made both to our data and to the data of Bakker and Segrè,[2] good agreement between these measurements is found. The results, however, are not compatible with the data of Mather and Segrè[3] when normalized to an absolute aluminum mean excitation potential of 166 ev,[4] or, still higher, to the mean excitation potential of 331 ev for emulsion.[5]

* Work done under the auspices of the U. S. Atomic Energy Commission.
† Permanent address: University of Lund, Lund, Sweden.
[1] M. C. Walske, Phys. Rev. **101**, 940 (1956).
[2] C. J. Bakker and E. Segrè, Phys. Rev. **81**, 489 (1951).
[3] R. Mather and E. Segrè, Phys. Rev. **84**, 191 (1951).
[4] Bichsel, Mozley, and Aron, Phys. Rev. **105**, 1788 (1957).
[5] W. H. Barkas, Nuovo cimento **8**, 201 (1958).

R11. Pion Production by Pions.* V. PEREZ-MENDEZ, J. C. CARIS, ROBERT W. KENNEY, AND W. A. PERKINS III, *University of California, Berkeley.*—The reaction $\pi^- + p \to \pi^+ + n$ was studied by bombarding a liquid hydrogen target with negative pions of energies 260, 317, 371, and 427 Mev. The second meson in the final state was detected by using a counter telescope which selected the π^+ by its characteristic π-μ decay. With the 260-Mev beam π^+ mesons were counted at 115° (c.m.); at 317, 371, and 427 Mev the differential cross section was measured for π^+ mesons emitted at 60°, 90°, 1[illegible] and 160° (c.m.). The angular distributions are nearly isotropic at 317 and 371 Mev but are peaked forward at 427 Mev. The total cross sections are: 0.14 ± 0.10 mb at 260 Mev; 0.71 ± 0.17 mb at 317 Mev; 1.93 ± 0.37 mb at 371 Mev; 3.36 ± 0.74 mb at 427 Mev. These results, which indicate that the cross section is much larger than the theoretical prediction based on the static model,[1] suggest that there is an additional mechanism responsible for pion production in this reaction. Reasonable agreement has been obtained by including a pion-pion interaction[2] in the production mechanism.

* Work done under the auspices of the U. S. Atomic Energy Commission.
[1] L. S. Rodberg, Phys. Rev. **106**, 1090 (1957); E. Kazes, *ibid.* **107**, 1131 (1957).
[2] L. S. Rodberg, Phys. Rev. Letters (to be published).

R12. Production and Decay of the K Meson.* SHERWOOD PARKER, BURTON J. MOYER, AND JOHN MOSHER, *University of California, Berkeley.*—The production and decay of strange particles have been studied by observing the space around a Bevatron target with a well-collimated gamma detector. Strange particles that have π^0 modes of decay can send gammas up to the detector from the subsequent decay of the π^0. The observed-gamma counting rate as a function of the detector and collimation position was then compared with that predicted for various assumptions about the production matrix element. The data require contributions to the counting rate from two known decay modes, $K^0 \to \pi^0 + \pi^0$ and $K^\pm \to \pi^\pm + \pi^0$, $\pi^0 \to \gamma + \gamma$. It is also consistent with limited contributions from $\Lambda^0 \to \pi^0 + n$, $\Sigma^+ \to \pi^0 + p$, and $\Sigma^0 \to \Lambda^0 + \gamma$, $\Lambda^0 \to \pi^0 + n$, but cannot give any information about these decays. The observed angular distribution requires that a significant part of the K^0 production be sharply peaked at high energies and at angles close to the line of collision of the incoming nuclei. The peaked part of the angular distribution can be fitted by $\cos^k\theta_{Kc}$, where θ_{Kc} is the polar angle of the K particle in the center of momentum system, and we have $k \geq 8$, with the best fits for $k = 12$ to 16.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

R13. π^--p Interactions at 1.3 Bev/c. M. BLAU, C. F. CARTER, AND A. PERLMUTTER, *University of Miami.*—Fundamental interactions of negative pions in emulsion were studied. By applying stringent requirements to the events, we believe that we have been able to separate free proton from edge collisions, unfortunately resulting in a small number of events. Nevertheless, we investigated the inelastic interactions with the production of single mesons, giving the angular and momentum distributions in the center-of-mass system. An attempt was made to interpret these data in terms of π-π and π-nucleon isobar models. In the latter case the angular distribution of the slow pion in the isobar frame deviates markedly from isotropy in the reaction $\pi^- + p \to \pi^- + \pi^0 + p$, while in the case $\pi^- + p \to \pi^- + \pi^+ + n$, the distribution seems more or less isotropic. Considerations of nonconservation of parity show a negative result.

SATURDAY AFTERNOON AT 1:30

Crawford 105

(F. A. JENKINS presiding)

Solid-State Physics

S1. Infrared Emission Studies of the Vibrational Relaxation in Nitric Oxide. J. J. ALLPORT, *Lockheed Missiles and Space Division.*—The vibrational relaxation of shocked nitric oxide has been observed by monitoring the increase in radiation at the characteristic vibratory frequency for nitric oxide, $\nu_0 = 1875.9$ cm^{-1}. The relaxation times observed by this method are an order of magnitude longer than those observed previously[1] using absorption techniques in the ultraviolet region of the spectrum. The experiments were carried out in the Lockheed Missile and Space Division 1-in. shock tube. Collimating slits, an infrared transmitting window, and two infrared transmission filters were used to isolate the radiation at the characteristic frequency. A liquid nitrogen cooled indium antimonide detector was used to monitor the radiation. The temperature range studied was from 500°K to 1200°K.

[1] F. A. Robben, Bull. Am. Phys. Soc. Ser. II, **3**, 320 (1958).

S2. Unimolecular Dissociation of Excited Ethane. CARL A. HELLER AND ALVIN S. GORDON, *U. S. Naval Ordnance Test Station.*—Excited ethane formed by the combination of an ethyl radical (from diethyl ketone) and a hydrogen atom (from mercury photosensitized H_2) contains more than enough energy to dissociate into two methyl radicals. Since this excited ethane may also be deactivated by collision there is a pressure dependence of the dissociation-deactivation ratio. This ratio has been measured in the presence of various gases. The lifetime of the excited ethane can be calculated and compared to similar excited molecules.

S3. Rayleigh Disk Measurements in Pure Superflow.* T. R. KOEHLER† AND JOHN R. PELLAM, *California Institute of Technology.*—The purpose of this experiment was to verify whether the superfluid component of liquid helium, flowing through a stationary normal fluid background, would exert the same torque on a Rayleigh disk as expected for perfect potential flow in classical hydrodynamics. The disk was suspended by a fine quartz fiber in a "superfluid wind tunnel" which is a device for obtaining pure superfluid flow at temperatures other than zero degrees using the fountain effect to pump helium through a chamber closed at each end by a jewelers' rouge plug. A disk 0.15 cm in radius was used with a quartz fiber of torsion constant of approximately 10^{-5} dyne-cm/deg, and the superfluid velocity was varied between 0.01 and 0.1 cm/sec. Observed torque showed the proper dependence on fluid velocity for each temperature investigated to within the experimental error of about ten percent. Also, by comparing results at different temperatures, it was possible to measure ρ_s/ρ as a function of temperature. This parameter was determined at thirteen different temperatures between 1.11°K and 2.11°K, and the results obtained agreed with previously accepted values.

* Supported in part by the Alfred P. Sloan Foundation, Inc., and the National Science Foundation.

† Standard Oil Company of California Fellow, 1957–1958.

S4. Application of Rayleigh Disk to Rotating Liquid Helium.* JOHN R. PELLAM, *California Institute of Technology.*—Experimental investigations[1] of the angular momentum content of rotating liquid helium II have depended heretofore on integrating torque-*vs*-time measurements of helium systems during angular acceleration and/or deceleration periods. A method capable of providing "instantaneous" observations of the state of rotating helium II by mechanical means is clearly desirable. The special characteristics of the Rayleigh disk for detecting fluid flow provide means for examining liquid helium under conditions of steady state rotation. Such a disk is suspended from a stationary (nonrotating) support by a fine quartz fiber and oriented to present an angle of 45° to the flow of helium produced by rotation of the containing vessel. Recent verification[2] that a Rayleigh disk responds to pure superflow (independently of the normal fluid) adds confidence to its application also to superfluid in rotating systems. Preliminary observations indicate markedly less torque exerted on the disk by rotating liquid helium II than by rotating helium I, suggesting nonrotation of superfluid.

* Supported in part by the Alfred P. Sloan Foundation, Inc.

[1] H. F. Hall, Phil. Trans. Roy. Soc. (London) **250**, 359 (1957); R. H. Walmsley and C. T. Lane, Phys. Rev. 112, 1041 (1958).

[2] T. R. Koehler and J. R. Pellam, preceding abstract.

S5. Capacitative Measurements on Zinc Sulfide Electroluminescent Cells. MAXWELL RATNER, *I.B.M.*—The average instantaneous capacity, at an instantaneous voltage, $u = V_0 \sin\omega t$, has been measured, following a technique suggested by H. Henisch,[1] over the ranges: $o < u < V$ v, where V_0 is 200 v and $100 < \omega/2\pi < 20\,000$ cps. This capacity C shows a variation with u and ω that apparently is dependent upon V. At very low voltages, C appears to exhibit dipole relaxation, with a relaxation frequency of 500–1000 cps. At high voltages (with V and ω fixed), C appears to vary as $u^{-\frac{1}{2}}\{1+\exp[-(a/u)]^{\frac{1}{2}}\}$ where a is determined from the brightness curve $B = B_0 \exp -(a/u)^{\frac{1}{2}}$. A tentative explanation for the behavior at high voltages is that space charge widening occurs within p-n barriers, together with impact ionization.

[1] H. Henisch, *Rectifying Semi-Conducting Contacts* (Oxford University Press, London, 1957).

S6. Band Structure of CdS and Absorption Spectrum. M. BALKANSKI AND J. DES CLOIZEAUX, *Laboratoire de Physique de l'Ecole Normale Superieure de Paris.*—An interpretation of the absorption spectra may be deduced from theoretical considerations on the structure of CdS crystals (wurzite type). The crystals are hexagonal without a center of symmetry and dichroic. It is thought that the conduction band is built from S states of Cd atoms (type Γ_7) and that the valence bands are built from the P states of sulfur atoms. The splitting, due to the crystal field, is of the same order of magnitude as the spin-orbit splitting. The crystal asymmetry as well as the spin-orbit coupling gives three separate valence bands corresponding to the P level. A fourth lower valence band could be due to the S level of the sulfur atom. The uppermost valence band is of Γ_9 type symmetry; the lower two are of Γ_7 type, and the lowest S level is also of Γ_7 type symmetry. Group theory consideration shows that light with a polarization vector, parallel to the hexagonal axis, may induce transitions from

the Γ_7 level only. For light having a polarization vector perpendicular to the crystal axis, transitions from all the valence bands are optically permitted. This explains the dichroism. The two limits of the absorption spectra,[1] corresponding to different polarized lights, give experimentally the separation between the Γ_9 type valence band and the Γ_7 type, which is about 0.02 ev. The theory has permitted to forecast that with each one of the four bands are associated exciton levels which have also been observed experimentally by Gross.[2]

[1] D. Dutton, see D. L. Dexter, J. Phys. Chem. Solids **8**, 473 (1959); M. Balkanski and R. D. Waldron, Phys. Rev. **112**, 123 (1958).
[2] E. F. Gross and M. A. Jakobson, Doklady Akad. Nauk S.S.S.R. **102**, 485 (1955).

S7. Photodesorption and Photoconductivity of ZnO Films.* D. B. MEDVED AND H. CREW, *Convair*.—Photodesorption from sintered ZnO semiconductor has been reported[1,2] and cited as evidence in favor of the model of chemisorption developed by Morrison[3] and Melnick.[4] According to the model, photoconductivity is considered due to formation of hole electron pairs; the hole migrates to the surface, recombines with a chemisorbed oxygen ion and the electron remains to contribute to the photoconductivity. Measurements of photoconductivity simultaneous with photodesorption have now been observed as a function of wavelength on films of ZnO prepared by oxidizing evaporated Zn on glass substrate. These observations indicate that a revision of the theory may be in order since photodesorption and photoconductivity have been observed to wavelengths greater than 6000 A. For wavelengths greater than 5750 A, pressure changes in a system under dynamic pumping were observed from 3×10^{-6} mm to 7×10^{-6} mm Hg in a period of minutes concomitant with photoconductivity. In ZnO thin films, wherein the "band gap" is assumed to be on the order of 3 ev the photodesorption process thus arises from transitions other than hole-electron pair formation.

* Supported by ARPA-AFCRC Contract No. AF 19(604)-5554.
[1] D. Medved, Phys. Rev. **98**, 237(A) (1955).
[2] Y. Fujita and T. Kwan, Bull. Chem. Soc. Japan **31**, 380 (1958).
[3] S. R. Morrison, Advances in Catalysis **7**, 259 (1955).
[4] D. A. Melnick, J. Chem. Phys. **26**, 1136 (1957).

S8. Optical Absorption of Solid Argon from 7.5 to 13 ev.* J. R. NELSON, *Cornell University and Convair*, AND P. L. HARTMAN, *Cornell University*.—Two absorption peaks centered at 8.75 ev (1410 A)[1] and 12.3 ev (1010 A) were observed in solid argon; the half-widths were about 1.5 ev and 0.6 ev, respectively. These peaks were observed in opacity measurements on thin films (thicknesses unknown) of solid argon at about 8°K in a considerably modified liquid helium cryostat.[2] The far ultraviolet detection technique previously described[1] of solidifying the argon on a sodium salicylate phosphor screen was used. This method obviated the need for a far ultraviolet transmitting substrate. Observation of the higher energy peak was made possible by use of a sliding Zapon window in front of the monochromator exit slits; the window was needed[2] to prevent the freezing of hydrogen from the hydrogen discharge light source on liquid helium cooled surfaces. In preliminary measurements it seemed as if multiplet structure were present in the first absorption peak. However, with further experimentation it was discovered that this structure was not real and was caused by incoherent scattered light from the grating. This effect will be described briefly.

* The research was performed at Cornell University and was supported in part by the Office of Naval Research.
[1] J. R. Nelson and P. L. Hartman, Bull. Am. Phys. Soc. Ser. II, **4**, 199 (1957).
[2] Hartman, Nelson, and Siegfried, Phys. Rev. **105**, 123 (1957).

S9. Comparison of the Effects of High Pressure and Low Temperature on the Absorption Spectra of Condensed Ring Aromatics in Nonpolar Solvents. W. W. ROBERTSON, *The University of Texas*.—As a result of the difference in the effect of London-van der Waals forces on the ground and excited states of light absorbers, the electronic spectra of condensed ring aromatics usually shift to the red upon solution in nonpolar solvents. An increase in hydrostatic pressure on the solution results in an increase in the red shift that is approximately linear with solvent density and is characteristic of the particular transition observed. A decrease in solvent temperature results in a corresponding frequency shift with increasing solvent density. However, the two effects seem to be somewhat different, and it is this difference that will be dealt with in this paper.

S10. Normal to Superconducting Transition in Thin Films.* F. W. SCHMIDLIN, E. C. CRITTENDEN, JR., JOHN N. COOPER, AND A. J. LEARN, *Space Technology Laboratories, Inc.*,—Superconducting thin films of indium and tin, immersed in helium and carrying a steady reference current, are transformed to the resistive state by current pulses of amplitude great enough for the total current (pulse plus reference) to exceed the critical current for the film under study. When a pulse terminates, it requires a measurable time for the normal-to-superconductive (*n-s*) transformation. This *n-s* transition time depends on pulse amplitude and pulse width. For constant width, as pulse amplitude is increased, the transition time increases to a maximum, decreases to a minimum, and finally increases again. A similar effect is observed for pulses of constant amplitude but increasing width. If the reference current is set below the critical current but too high for the film to make the *n-s* transition, the *n-s* transition can be initiated by an additive pulse, and there exists a pulse which minimizes the transition time. When the reference current exceeds the critical current, a momentary return to the intermediate state may be induced by a pulse. These effects did not occur below the helium λ point.

* Work supported in part by the Office of Naval Research.

S11. Transition Times to the Superconductive State for Thin Films.* JOHN N. COOPER, E. C. CRITTENDEN, JR., A. C. LAUER, AND J. K. NUNNELY, *U. S. Naval Postgraduate School and Space Technology Laboratories, Inc.*—The times required for the transformation of thin indium films from normal to superconductive have been determined as in the preceding paper. With a steady reference current between 0.1 and 0.6 of the critical current passing through a film, current pulses were applied to drive the film resistive and the *n-s* transition time τ was measured from oscilloscope photographs of the potential difference developed across the film. Pulse length was 20 μsec, sufficient to make τ independent of the duration. As pulse amplitude increased, τ passed through a maximum, then a minimum, and finally increased indefinitely. At the maxima, transition times for the films vary from 10 to 180 μsec. At the minima, values are 1 μsec or less and are essentially independent of film thickness, substrate, and reference current. For a given film and temperature the maximum occurs at the same value of total current (pulse plus reference) over a wide range of reference currents. Similarly the minimum comes at a constant total current. Between maximum and minimum, the logarithm of the transition rate $1/\tau$ is linear with total current with the slope decreasing as the film thickness is increased.

* Work supported in part by the Office of Naval Research.

SATURDAY AFTERNOON AT 1:30

Crawford 103

(J. W. M. DUMOND presiding)

Low-Energy Nuclear Physics

T1. Short-Lived Isotopes of Ce and Pr.* D. C. HOFFMAN AND W. R. DANIELS, *Los Alamos Scientific Laboratory* (introduced by C. J. Orth).—The following previously-unreported, short-lived isotopes of Ce and Pr have been identified: Ce^{147}, 1.2 ± 0.1 min; Ce^{148}, 0.7 ± 0.2 min; Pr^{147}, 12.0 ± 0.5 min; Pr^{148}, 1.95 ± 0.15 min. The half-life of Pr^{146} was determined to be 24.0 ± 0.1 min.[1] Ce half-lives were determined by following the gross β decay of Pr daughters milked at suitable intervals from fission-product Ce. Similar Pr samples were used to determine the Pr half-lives directly and to study the radiations of the Pr isotopes with β- and γ-scintillation spectrometers. Pr^{146} was found to exhibit photopeaks at 0.92, 1.02, 1.36, $\sim$2.2, and $\sim$2.7 Mev, in addition to the previously observed[2] γ rays at 0.46, 0.59, 0.75, and 1.49 Mev. Photopeaks at 0.32, 0.58, 0.64 (complex), 0.92 (complex), 1.25, and $\sim$1.7 Mev were attributed to Pr^{147}. The observation of a prominent 300-kev γ ray in the decay of the 1.95-min Pr^{148} is consistent with Coulomb excitation experiments[3] which showed the existence of a 2+ level at 300 kev in Nd^{148}. Results of β-γ and γ-γ coincidence studies will be discussed.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] This is in good agreement with the value of 24.0 min reported by J. D. Knight and D. P. Ames, LASL Classified Report WASH-62 (December, 1951).

[2] Bernstein, Markowitz, and Katcoff, Phys. Rev. **93**, 1073 (1954).

[3] Simmons, Van Patter, Famularo, and Stuart, Phys. Rev. **97**, 89 (1955); N. P. Heydenburg and G. M. Temmer, *ibid.* **100**, 150 (1955).

T2. Short-Lived Isotopes of Nb and Zr from Fission.* C. J. ORTH AND R. K. SMITH, *Los Alamos Scientific Laboratory.*—Nb^{98}, Nb^{99}, and Zr^{99}, plus three other short-lived β emitters tentatively identified as Nb^{100}, Nb^{101}, and Zr^{98}, have been observed in the niobium and zirconium fractions rapidly separated from U^{235} fission products. Their properties and bases of identification are as follows. Nb^{98}: $T_{\frac{1}{2}}=51.5\pm1.0$ min[1]; E_γ(Mev) $=0.330\pm0.005$, 0.720 ± 0.005, 0.780 ± 0.005, 1.16, 1.44, 1.52, 1.68, 1.88, 1.93, 2.24, 2.7; $E_{\beta\,\max}=3.1$ Mev; $Q_{\beta^-}=4.6\pm0.2$ Mev; confirmed by $Mo^{98}(n,p)$; not produced by Zr^{98} β decay. Nb^{99}: $T_{\frac{1}{2}}=2.4\pm0.2$ min (by successive extractions of Mo^{99}); E_γ(Mev) $=0.100\pm0.002$, 0.260 ± 0.005; previously identified by $Mo^{100}(\gamma,p)$.[2] Zr^{99}: $T_{\frac{1}{2}}=35\pm5$ sec (by successive extractions of $Nb^{99}-Mo^{99}$). Nb^{100}: $T_{\frac{1}{2}}=3.0\pm0.3$ min (by decay of 0.53-Mev photopeak); E_γ(Mev) $=0.140\pm0.005$, 0.360 ± 0.010, 0.450 ± 0.010, 0.530 ± 0.010, 0.65, 2.2, 2.3, 2.65, 2.8; strongest γ peak, 0.530 Mev, agrees with the γ observed in Mo^{100} Coulomb excitation. Nb^{101}: $T_{\frac{1}{2}}=1.0\pm0.2$ min (by successive extractions of Mo^{101}-Tc^{101}). Zr^{98}: $T_{\frac{1}{2}}=60\pm20$ sec (by gross Zr β decay measured through heavy absorber). The Nb^{98} daughter of Zr^{98} has not been observed; the very energetic β's found in Zr decay are probably those of a short-lived isomer of Nb^{98} in equilibrium. A partial Zr^{98}-Nb^{98} decay scheme will be discussed.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] This value agrees with the value of $\sim$55 min measured by D. Troutner, Washington University (private communication).

[2] Duffield, Hsiao, and Sloth, Phys. Rev. **79**, 1011 (1950).

T3. Compound Nucleus Decay Leading to Fission.* LAWRENCE WILETS, *University of Washington.*—In a particular representation where the state vectors are not eigenstates of the Hamiltonian, coupling terms remain which cause "virtual" or "real" transitions among states. An appropriate choice of representation depends upon the physical processes involved. The decay of a compound nucleus, especially by fission, is considered. The strong coupling representation of the unified model is employed, with surface oscillations inducing transitions among states of the representation. A diffusion equation is derived to describe the flow of probability among the states available within constraints. An estimate of the characteristic relaxation time for arriving at statistical equilibrium is obtained. Only when the relaxation time is short compared with a basic reaction time are statistical arguments valid to evaluate the reaction rate. The relevant reaction time in the fission process is a collective period. The necessary condition appears to be satisfied for excitation energies more than a few Mev above threshold. Arguments are presented to show why equilibrium may not be maintained at lower energy. Thus the usual estimate of the number of open channels, $2\pi\overline{\Gamma}_f/D$, would give a number lower than what one would estimate simply from penetrability of the fission barrier.

* Supported in part by the U. S. Atomic Energy Commission.

T4. Spontaneous Fission Yields of Cf^{252}.* W. E. NERVIK, P. C. STEVENSON, H. G. HICKS, H. B. LEVY, J. B. NIDAY, AND J. C. ARMSTRONG, *University of California, Livermore.*—A radiochemical investigation has been made of the fission yield curve for the spontaneous fission of Cf^{252}. One source of 1×10^6 and another of 2×10^7 fissions per minute were used to obtain the data. Thirty-six active nuclides between mass numbers 77 and 166 were separated, identified, and their fission yields calculated. Upper limits were set for six other nuclides. The fission yield curve has maxima of 6.2% at masses 107 and 141 with the "width at $\frac{1}{10}$ maximum" of each peak being approximately 27 mass units. There is a very narrow "trough" with a minimum value of 1×10^{-2}% at mass number 124. In addition, while the curve as a whole is symmetrical about mass 124, each peak is not symmetrical about its own maximum, being significantly spread toward the most asymmetric fission modes. No evidence was seen of fine structure in either peak; nor was there evidence of activities which could be ascribed to ternary fission events, upper limits of 10^{-4}% fission yield being set for individual nuclides between mass numbers 28 and 72.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

T5. $T(p,n)He^3$ Reaction.* J. E. YOUNG AND W. M. VISSCHER, *Los Alamos Scientific Laboratory.*—Calculations have been carried out for the subject reaction using three computational procedures. These procedures imply the use of certain direct interaction models whose validity one hopes to assess. In particular, reaction cross sections have been calculated in Born approximation for pickup of a deuteron core; and nucleon exchange. They have also been calculated in distorted wave approximation taking into account competing nucleon ejection and nucleon exchange. A transparent model of the nucleus is assumed for the nucleon core interaction, while the exchange and ejection processes are assumed to occur from the proton tails. Finite range forces have been used in the distorted wave calculation and also in the Born approximation for nucleon exchange. Coulomb forces have been used in the distorted wave calculation, and spins have been included for all calculations. These calculations span the energy range from 1.5 to 5 Mev.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

T6. Angular Distribution of Fragments in the Fast Neutron-Induced Fission of Th^{230}, U^{234}, U^{236}, and U^{238}.* J. E. SIMMONS AND R. L. HENKEL, *Los Alamos Scientific Laboratory.*—Angular distributions of fragments have been measured using a multiangle, gas-filled counter. Neutrons of energy between 0.6 and 9 Mev were used to induce fission. For the uranium isotopes the anisotropy—(0°/90°) intensity ratio—was approximately constant at values near 1.2 between 2 and 6 Mev; for the thorium isotope the value was closer to 1.1 in this energy range. At 6 Mev the anisotropy increased abruptly, in a manner consistent with previous observations on Th^{232} and U^{233}. The highest value of anisotropy occurred for Th^{230}; it attained a value of approximately 2.3 at 7 Mev. Near the fission thresholds, the anisotropies showed considerable variation. For the case of U^{236} in particular, near 0.85 Mev, the anisotropy indicated preferred emission at ninety degrees. In the energy range between 2 and 5 Mev the angular distributions have been fitted to theoretical[1,2] expressions. The values of the theoretical parameters thus obtained allow correlations of the present data and predictions for nuclei which have not yet been investigated.

* This work performed under the auspices of the U. S. Atomic Energy Commission.

[1] I. Halpern and V. M. Strutinski, *Proceedings of the Second International Conference on the Peaceful Uses of Atomic Energy* (United Nations, Geneva, 1958), Paper .15/P/1513.

[2] J. Griffin (to be published).

T7. Nuclear Alignment of Tb^{160}.* C. E. JOHNSON AND D. A. SHIRLEY, *University of California, Berkeley.*—Tb^{160} has been oriented in a single crystal of neodymium ethyl sulfate in which about 10 microcuries of active terbium had replaced some of the neodymium ions. The angular distributions of all the γ rays were measured as a function of temperature between 0.02°K and 1.03°K by use of 3×3-inch sodium iodide crystals and 100-channel pulse-height analyzers. The results for each γ ray could be fitted to functions of the form $I(\theta)$: $1+A_2P_2(\cos\theta)$, when A_2 is temperature-dependent. For the 875-kev γ ray A_2 is positive and its value shows that the transition is mainly quadrupole with a 6% admixture of dipole. A_2 is negative for the 300-, 1180-, and 1270-kev γ rays, which are shown to be dipole with about 0%, 1%, and 16% admixtures of quadrupole respectively. By making assumptions about the spin and β decay of Tb^{160} the nuclear magnetic moment and electric quadrupole moment may be estimated.

* Work done under the auspices of the U. S. Atomic Energy Commission.

T8. Investigation of the Excited Levels of Pd^{106}. DANIEL J. HOREN, *Stanford University* AND HORACIO E. BOSCH,* *University of California, Berkeley.*—Palladium-106 exhibits a complex level structure at an energy approximately twice the energy of the first excited state, one level with character 0+ at 1.137 Mev and one at 1.128 Mev with character 2+. The gamma rays from Rh^{106} (30 sec) and Ag^{106} (8.3 days) have been studied with a 3 in.×3 in. NaI(Tl) crystal in order to investigate the feeding of the above-mentioned levels by radioactive decay. Rhodium-106 was obtained in equilibrium with a Ru^{106} source from Oak Ridge. Silver-106 (8.3 days) was produced by bombarding Rh^{103} with alpha particles (<14 Mev). A chemical separation was performed. Although the energy of the projectile was estimated to be less than the threshold for $(\alpha,2n)$ reaction, in the sample were observed gamma rays with longer half-life than 8.3 days. From a study of samples containing relatively more Ag^{108} it was possible to determine more accurately which gamma rays belonged to Ag^{106}. The decay of the sample was followed for six months and the gamma rays of 0.180, 0.285, 0.430, 0.450, and 0.680 Mev were assigned at Ag^{106} (40 days). The gamma rays of 0.230, 0.410, 0.520, 0.620, 0.725, 0.805, 1.030, 1.150, 1.250, 1.540, 1.770, 1.850, and 2.250 Mev correspond to Ag^{106}.

* Fellow from Consejo Nacional de Investigaciones Científicas y Técnicas, and on leave of absence from Comisión Nacional de Energía Atómica and Universidad de La Plata, Argentina.

T9. Cross Sections for the $B^{11}(n,\gamma)B^{12}$ Reaction.* R. G. JOHNSON, W. L. IMHOF, AND F. J. VAUGHN, *Lockheed Missiles and Space Research Laboratory.*—Cross sections for the $B^{11}(n,\gamma)B^{12}$ reaction have been measured at thermal energy and at energies between 150 kev and 1780 kev. Targets containing mixtures of boron and iodine were used for all cross-section measurements. The neutron flux at each energy was determined from the induced I^{128} activity, using the known $I^{127}(n,\gamma)I^{128}$ cross section. The B^{12} activity was identified by the observed 20 msec half-life. A pulsed neutron source was produced by intermittently bombarding a lithium target with protons from a Van de Graaff accelerator. The scintillator pulses were analyzed between the 100-msec beam bursts using a time-to-pulse height converter and a 100 channel pulse-height analyzer. A resonance in the cross section, with a preliminary peak value of 0.025 mb has been observed at 430 kev corresponding to the known energy state in B^{12} at 3.76 Mev, and the radiation width for this level is found to be ~0.2 ev. Resonances were not observed at neutron energies corresponding to the next two higher states at 4.53 Mev and 4.99 Mev. The cross section at thermal energy is found to be ~5 mb.

* Supported by the joint program of the U. S. Atomic Energy Commission and the Lockheed General Research Program.

T10. Resonance Absorption of Gamma Rays in Crystals.* P. P. CRAIG, J. G. DASH, A. D. MCGUIRE, AND D. E. NAGLE, *Los Alamos Scientific Laboratory.*—It recently has been demonstrated[1] that in the case of nuclei bound in a crystal at low temperature there can be an appreciable probability that gamma-ray emission takes place with the recoil momentum being absorbed by the crystal as a whole, i.e., with no phonon creation in the crystal and with essentially no "doppler-shift" of the emitted gamma ray. In a cold crystal the inverse absorption may take place with no nuclear recoil, so that the cross section for the absorption of the nonshifted gamma radiation may reach large values characteristic of resonance absorption. In the present work, the 129-kev gamma ray of Ir^{191} was absorbed in metallic Ir^{191}. The absorption cross section was found to have a temperature-dependent part which increased below room temperature to 57±8 barns at 1.4°K. By moving the source at constant speed with respect to the absorber at low temperature, a doppler shift was imposed on the emitted gamma rays which destroyed the resonance and reduced the absorption cross section to the room temperature value. The half-width of the cross section *vs* velocity curve is 2.2 cm/sec corresponding to a width of 9.5×10^{-6} v for the first excited level in Ir^{191}.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] R. L. Mössbauer, *Z. Physik* **151**, 124 (1958); *Z. Naturwissenschaften* **14**, 211 (1959).

T11. Theoretical Predictions for the Spectra of the Odd-Mass Tellurium and Xenon Isotopes.* NORMAN K. GLENDENNING, *Lawrence Radiation Laboratory, Berkeley.*—Interesting systematics are displayed in the spectra of the odd-mass tellurium and xenon isotopes, in particular the migration (with increasing N) of the first excited state (3/2+) toward the ground state (1/2+) until the former becomes the ground state. Recent developments in the treatment of the many-body problem[1,2] yield an understanding of these systematics. The best known spectrum, Te^{125}, is very well reproduced by considering one neutron (which has available the $s_{\frac{1}{2}}$ and $d_{\frac{3}{2}}$ single-particle levels) coupled to surface vibrations of up to three phonons. Theoretical predictions are made for the spins of the excited states of Te^{125} where these are not well known, and agreement is obtained with the known spins (ground and first excited). In addition calculations are made for neighboring odd-N tellurium and xenon nuclei using for a guide to the single particle spacing, the predictions of the above mentioned

treatment of the many-body problem. Spin assignments and new levels are predicted.

* This research was supported by the U. S. Atomic Energy Commission.
[1] Ben R. Mottelson, Lectures at University of California, Berkeley, 1959 (unpublished).
[2] S. T. Belyaev, Kgl. Danske Videnskab. Selskab Mat.-fys. Medd. 31, No. 11 (1958).

T12. Decay of Sb^{126}, Sb^{128}, and Sb^{130}. HORACIO E. BOSCH,* *Lawrence Radiation Laboratory, Berkeley.*—In order to investigate the systematic behavior of excited nuclear levels in even-even nuclei near closed shells, the beta decay schemes of Sb^{126}, Sb^{128}, Sb^{130}, and their isomers were studied. These have been produced by bombarding enriched tellurium isotopes with fast neutrons. A chemical separation was performed in every case. The beta spectra were measured with an anthracene crystal. The gamma spectra were determined with a 3 in.×3 in. NaI(Tl) crystal. The half-lives of 18.8 min and 11 days are assigned to the two Sb^{126} states; 19.7 min and 10 hours, to the Sb^{128} states; and 30 min and 330 min, approximately to the Sb^{130} states. The gamma spectrum from Sb^{126} (11 days) is composed of the following rays: 0.160, 0.425, 0.685, 0.755, 0.850, and 1.060 Mev. That of the Sb^{128} (10 hours) is composed of 0.160, 0.388, 0.515, 0.743, 0.860, and 1.180 Mev gamma rays. That of the Sb^{130} (330 min) is composed of 0.160, 0.240, 0.450, 0.500, 0.850, and 0.940 Mev gamma rays. Partial level schemes for the tellurium daughter nuclei will be presented and discussed.

* Fellow from Consejo Nacional de Investigaciones Científicas y Técnicas, and on leave of absence from Comisión Nacional de Energía Atómica and Universidad de La Plata, Argentina.

SATURDAY AFTERNOON AT 1:30

Crawford 209

(C. GREGORY presiding)

Theoretical Physics

U1. Classical Quantum Motion of a Particle with Spin. H. C. CORBEN, *Ramo-Wooldridge Research Laboratory.*—The classical equation of motion for the spin of a particle of charge e, mass m, magnetic moment $\boldsymbol{\mu}=g\boldsymbol{\sigma}$ moving in an inhomogeneous field is modified in order to be automatically consistent with the requirement that the electric dipole moment $\boldsymbol{\varepsilon}$ vanish in the rest system, independently of the equation of motion for the particle itself. This latter equation then contains a term describing the interaction of $\boldsymbol{\mu}$ and $\boldsymbol{\varepsilon}$ with the inhomogeneous field and implies that $\boldsymbol{\mu}\cdot(\partial^2\mathbf{B}/\partial t^2)+\boldsymbol{\varepsilon}\cdot(\partial^2\mathbf{E}/\partial t^2)=-\frac{2}{3}e^2v_iv_i(\cdot=d/ds)$. If radiation damping is neglected and the Bohr-Sommerfeld quantum condition is applied to circular motion of such a particle (with $g=e/mc$) in a Coulomb potential Ze/r, there exists in addition to the usual atomic orbits a set of orbits of radii $r_n\doteq Ze^2/nmc^2$, and total energy $W=mc^2(n^2/2Z\alpha\pm n)(\alpha=e^2/\hbar c)$, the sign being that of the circulating charge. If applied to the motion of electrons and positrons around an atomic nucleus, this yields qualitative agreement with the observed upper limits to β^-, β^+, and γ-ray spectra. For $Z=1$, corrections for the motion and magnetic moment of the proton are no longer negligible. If the corresponding relativistic quantum theory does not exhibit similar localized unstable positive energy states it would appear that the correspondence principle breaks down at distances of order r_n.

U2. Completely Deterministic Quantum-Mechanical Treatment of a Particle in a Box.* J. P. WESLEY, *University of California, Livermore.*—As the simplest example of the completely deterministic quantum-mechanical theory, the particle in a box illustrates most of the qualitative features of bound particle trajectories in general. The particle motion is confined to a restricted region in space, or a "cell." The center of each cell possesses a stagnation point where the particle will remain stationary for all time if placed at this point with zero initial velocity. The particle yields a classical macroscopic trajectory when it is placed initially on a cell boundary. Assuming all initial positions equally likely the probability distribution over all initial conditions is similar, but not equal, to $\psi\psi^*$.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

U3. Approximate Inversion with Error Bounds of a Class of Linear, Variable Coefficient Scattering Operators. WILLIAM A. JANOS, *Convair.*—The perturbation method of the Neumann series expansion for the inverse of the identity plus a small operator is used to obtain an estimate of the error in approximating a given differential operator, in particular a scattering operator, by one which is "close" to it in a preassigned manner and has more conveniently characterized parameters allowing a calculable Green's function. A method is established for the derivation of such a simpler solution by suitably approximating the coefficients of the given operator in a piecewise sense over the domain of the independent variable. Thus, a related scattering problem is solvable precisely rather than approximately, and this solution falls within known and diminishable confidence limits of the more complex solution It is shown that the calculational aspects of the related problem in the case of elastic scattering are no more than those required in the solution of a linear first order recurrence relation between two-component vectors, hence easily computed digitally. The conditions necessary for a feasible approximation are shown to be less stringent than those for the Born approximation. Error bounds in scattering amplitude, differential and total cross section and phase shifts are shown determinable for both total and partial wave scattering operators.

U4. Field Operators for Bosons with Impenetrable Cores. I. Equations which Replace the Commutation Rules.* A. J. F. SIEGERT, *Northwestern University.*—Field operators representing particles with impenetrable cores cannot satisfy the usual commutation rules. While the customary derivation of the second quantization formalism cannot be applied to the case of particles with nonintegrable interaction potentials, the field operators $\psi(\mathbf{x})$ and $\psi^\dagger(\mathbf{x})$ can be defined by a matrix representation which exhibits them explicitly as transformations of functions of N position vectors into functions of $N-1$ and $N+1$ position vectors, respectively. The assumption of impenetrable cores is introduced in this definition by taking the matrix elements which lead to prohibited configurations of position vectors equal to zero. Equations which replace the usual set of commutation rules are derived from this definition for the case of hard sphere interaction. Conversely it is shown that results which follow from the commutation rules in the standard formalism, follow from the new set of equations with the changes obviously required by the assumption of impenetrable spherical cores. For example, the operator for the number of particles in a finite domain has as eigenvalues

the non-negative integers not exceeding the largest number of hard spheres which can be placed into the domain.

* Program supported by the National Science Foundation and the Office of Naval Research.

U5. Symmetry of Gravity Forces on the Free Neutron. A. W. McREYNOLDS AND W. L. WHITTEMORE, *General Atomic.** —It has been shown in a previous experiment[1] that the trajectory of a slow neutron beam has a curvature corresponding to the same gravity acceleration g as observed for bulk matter. The value of g thus measured represents an average over a large number of neutrons of random spin orientation. Further experiments are described in which polarized neutron beams were used to determine whether the force of gravity on a free neutron is spherically symmetrical or dependent on the relative directions of spin and field. If the gravity force were different for neutrons with spins parallel and antiparallel to the field, two effects should be observed. The curvature of a slow neutron trajectory should differ for the up and down polarization states. Also, transition from one state to the other should represent a change in energy corresponding to the degree of asymmetry. Observations which have been made both on the trajectory curvature of vertically polarized beams and on the energy before and after transitions between polarization states indicate no asymmetry greater than about one percent of the value of g.

* John Jay Hopkins Laboratory for Pure and Applied Science, General Atomic Division of General Dynamics Corporation, San Diego, California. Experimental work performed at Brookhaven National Laboratory.
[1] A. W. McReynolds, Phys. Rev. **83**, 172 (1951).

U6. Photon Rest Mass.* RUTH F. KILBY AND JOHN H. NUCKOLLS, *Lawrence Radiation Laboratory, Livermore.*—Edward Teller recently observed that, if there is a variation of the velocity of electromagnetic radiation with frequency, it might be detected by measuring arrival times of radiation from a nuclear explosion at a distance of the order of an astronomical unit from the earth.[1] We propose that an increase of velocity with frequency could be evidence of a finite photon rest mass. The theory of relativity would then be essentially unaffected if c were defined as the maximum velocity with which information can be transmitted. The observed difference between the separations of the visible and radio images of the colliding galaxies in Cygnus could be explained by a photon rest mass of $\sim 10^{-41}$ g. This amount would produce a variation of velocity with frequency which is within the experimental errors of terrestrial measurements for visible light and radar waves. It would not cause noticeable effects in astronomical observations of novae, binary stars, or cepheid variables. Teller's experiment could probably detect a photon rest mass of the order of 10^{-42} g or less, depending upon the free electron density in space.

* Work performed under auspices of the U. S. Atomic Energy Commission.
[1] E. Teller, Space Digest, 144 (June, 1959).

U7. Thermodynamic Significance of the "Cutoff" Used in the Electronic Partition Function. SIDNEY W. BENSON, *University of Southern California,* AND JERRY H. BUSS AND HOWARD MYERS, *Douglas Aircraft Company, Inc.*—Application of statistical thermodynamics to gases at elevated temperatures demands a consistent method of determining the proper number of electronic energy levels to be considered in formulating the electronic partition function. This is necessitated by the divergent series caused by terms composed of ever-increasing degeneracy and finite exponential contributions. In the past, solutions to the problem have ranged from simplified "magic number" approaches to sophisticated density dependent cutoffs where the important parameter is the average distance between nuclei. These previous attempts are difficult to apply and theoretically disturbing. A temperature dependent cutoff eliminates many of the objections and will be presented as a more meaningful criterion. Experimental examples will be called upon to demonstrate the ability of this new method to predict what have been considered anomalies. This approach does not change the calculated thermodynamic variables significantly with the exception of concentration, which is varied radically. This could explain many of the superequilibrium concentrations of electrons which have been measured and have thus far confused the results of shock-tube experiments.

U8. On the Behavior of the Scattering Phase Shift in the Presence of Inelastic Processes.* MALVIN A. RUDERMAN AND CHARLES M. SOMMERFIELD, *University of California, Berkeley.* —Under consideration are processes involving inelastic scattering which may be described in terms of a nonlocal, energy-dependent, complex potential. It is found, with suitable restrictions, that a potential which describes the propagation of fields with a speed less than that of light yields a complex scattering phase shift whose real part decreases by $(n_b - n_f)\pi$ as the energy increases from threshold to infinity. Here n_b is the number of bound states produced by the potential and n_f is the number of elementary fields in the process. To the extent that such potentials provide adequate descriptions of the interactions, experimental determination of the energy behavior of the scattering phase shifts will allow a distinction to be made between those fields to be taken as elementary and those to be considered as composite.

* Supported in part by the U. S. Air Force Office of Scientific Research and by a grant from the National Science Foundation.

U9. Compton Scattering Low-Energy Theorem via Dispersion Relations. IRWIN MANNING, *U. S. Naval Research Laboratory.*—Following a suggestion by G. Feldman and W. Wada, we have examined the application of dispersion relations to the scattering of very low energy photons by a particle of spin ½. The present proof of this theorem borrows much from Akiba and Sato[1] and closely parallels that given by F. E. Low.[2] The major difference appears as the replacement of one assumption by another. With the dispersion relations the low-energy cross section is given by the "bound state" contribution, and this term does not require any assumptions regarding the behavior of the nucleon form factors for nonzero momentum transfer. On the other hand, we are forced to make what are by now standard assumptions regarding the applicability of the dispersion relations, including an assumption of convergence for a set of three integrals. The Kroll-Ruderman theorem concerning photomeson production will be discussed.

[1] Akiba and Sato, Progr. Theoret Phys. (Kyoto) **19**, 93 (1958).
[2] F. E. Low, Phys. Rev. **96**, 1428 (1954).

U10. Some Regularities Concerning the Composition of Crystalline Matter. N. EFREMOV, *New York.*—The composition of the most abundant silicates, which practically constitute the crystalline part of the earth's crust, may be derived from a series of primary formulas in which the elements of the IV-th group are represented by Si^{4+} and the collective expression for the metals (H, Na, K, Mg, Al, etc.) by the bivalent Me. In these formulas (see the following) the valence relations (R_v) between the valence of Si^{4+} and the total valence of the metals are represented by simple small numbers: 1, 2, 3, etc.

Valence relations $= R_v$	Primary formulas	Formulas of corresponding silicates
$Si^{4+}:Me_2^{2+}=4:4=1$	$Me_2^{2+}SiO_4$	Mg_2SiO_4 or $NaAlSiO_4$
$Si^{4+}:Me^{2+}=4:2=2$	$Me^{2+}SiO_3$	$MgSiO_3$
$Si_4^{4+}:Me^{2+}=12:4=3$	$Me_2^{2+}Si_2O_5$	$NaAlSi_2O_5$ or $KAlSi_2O_5$

Substituting Me in these primary formulas by Mg^{2+} or Me_2 by $Na^{1+}Al^{3+}$ etc., we receive the formulas for the most abundant silicates. The same Rule of Four[1] concerning the chief isotopes is also demonstrated by this series of primary formulas.

[1] N. Efremov, Bull. Am. Phys. Soc. Ser. II, **4**, 319 (1959).

SUPPLEMENTARY PROGRAMME

SG11. The Neutrino and the Decay of the Hyperons. LEONARD S. LEVITT, *Stevens Institute of Technology.**—It has been pointed out[1] that the masses of the hyperons (in units of electron masses) are related to the proton mass (p^+), the mu-meson mass ($\mu^\pm$), and the fine structure constant[2] ($\alpha=1/137$): $\Lambda^0=p^++\mu+1/\alpha=2180$; $\Sigma^+=p^++\mu+2/\alpha=2317$; $\Xi^-=p^++\mu+4/\alpha=2591$. The stable end product of the decay of all hyperons is the proton, and along the decay route at least one $\mu^\pm$ is formed. For the Λ^0 and $\Sigma^\pm$ particles there are two main routes of disintegration, one in each case leading to the intermediate formation of a mu meson: $\Lambda^0\rightarrow p^++\mu^-+\nu^0$; and $\Sigma^\pm\rightarrow p^++e^-+\mu^\pm+2\nu^0$. The Ξ^- particle can take the following course in its transformation to a proton and mu meson: $\Xi^-\rightarrow p^++e^-+\mu^-+4\nu^0$. On comparing the mass relations with these decay sequences, we observe that what appear as $(1/\alpha)$'s in the former become the corresponding number of neutrinos in the latter. The implication is that neutrinos are each in some way associated with a mass of $(1/\alpha)m_e$ in these decays.

* To be given at the end of Session G if the Chairman rules that time permits.
[1] L. S. Levitt, Current Science **27**, 131 (1958); Bull. Am. Phys. Soc. Ser. II, **4**, 175 (1958).
[2] These relations have recently been explained theoretically in the relativistic rotator model for the elementary particles. [E. J. Sternglass, Bull. Am. Phys. Soc. Ser. II, **4**, 228 (1959)].

SN9. New "Charles' Law" at Extreme Pressures. LEONARD S. LEVITT, *Stevens Institute of Technology.**—In a previous work[1] it has been demonstrated, using Bridgman's data for N_2 and Ar that the V-T isobars are excellent straight lines above 1000 atmos, the same pressure at which the isotherms begin to obey the law[1] $P=Ce^{B/V}$, where B and C are constants characteristic of a particular gas. Since the isobars converge to a single point on the V axis at 0°K, they are represented by $V=V_0+a_pT$, where V_0 is the incompressible volume at 0°K and $a_p=(\partial V/\partial T)_p$. Eliminating a_p for two different temperatures at constant pressure gives an exact V-T relation for high pressures comparable to Charles' law: $V_2=V_1(T_2/T_1)+V_0(1-T_2/T_1)$. The slope of the isobars, a_p, decreases with increasing pressure, and it is found that $a_p\simeq R'/P$, where R' is a new gas constant for high pressures, which at first increases somewhat with pressure and reaches the same *limiting* value of $\frac{3}{2}R$ at 6000 atmos for both N_2 and Ar. Above this pressure, then, $(\partial V/\partial T)_p=R'/P$, and $(\partial^2V/\partial T^2)_p=0$, and therefore $(\partial C_p/\partial P)_T=0$. The entropy decrease due to compression is found to be $-\Delta S=\int_{P_1}^{P_2}(\partial V/\partial T)_P dP=R'\ln(P_2/P_1)=R'B(1/V_2-1/V_1)$.

* To be given at the end of Session N if the Chairman rules that time permits.
[1] L. S. Levitt, Bull. Am. Phys. Soc. Ser. II, **3**, 340 (1958); J. Phys. Chem. (to be published); **58**, 573 (1954).

SO12. Thermodynamic Properties of Fluid Flow Across a Magnetic Field. II.* K. P. CHOPRA, *University of Southern California*, AND INDERJIT SINGH, *Oil and Natural Gas Commission, Government of India* (introduced by H. T. Yang).†—This paper is devoted to the study of the effects of a transverse magnetic field on some of the flow characteristics of a perfectly conducting fluid. It is seen that the effect of an area change (as in a nozzle) on the subsonic or supersonic flow is not affected by the presence of the magnetic field. However, it is demonstrated that the presence of a transverse magnetic field is conducive to the formation of a shock wave. The analog of Prandtl's equation is derived and the expression for the critical speed is obtained. It follows that the flow is definitely subsonic if the stream velocity is less than or equal to the critical speed. On the contrary, if the stream velocity exceeds the critical speed, the hydromagnetic flow may be supersonic, sonic or subsonic. Use of the jump conditions leads to the analog of Prandtl's relation for shock waves. The expressions for jumps in internal energy and enthalpy across the shock front readily follow. New Hugoniot function is defined and the surface represented by the Hugoniot equation in the (τ,p^*,H) space is a hyperbolic paraboloid. As in ordinary shock waves, the entropy change across the shock-front is of the third order in specific volume.

* Supported in part by the U. S. Air Force Office of Scientific Research.
† To be given at the end of Session O if the Chairman rules that time permits.

SQ12. 708-kev Gamma Ray in P^{30}. J. J. SINGH, *University of Kansas.**—A detailed study of the reaction $Si^{29}(p,\gamma)$ at proton energy of 414 kev has been made. Strong transitions have been observed to the doublet at 700 kev while the transition to the ground state is much weaker. Angular distributions of all the observed gamma rays have been measured. In order to explain the intermediate unobserved angular distribution of the "700-kev" gamma ray, we had to assume that the 708-kev gamma ray is a strongly mixed radiation. It could be due to inhibition of M_1 transition (L-forbidden or T-forbidden) or enhancement of E_2 transition. Various possibilities which could account for this strong mixing will be discussed.

* To be given at the end of Session Q if the Chairman rules that time permits.

SS10. Photoelectric Theory of Photosynthesis. V. Near Infrared Electronic Spectrum of Magnesium in Chlorophyll. LEONARD S. LEVITT *Stevens Institute of Technology.**—It has been postulated in the photoelectric (or photoconductive) theory of photosynthesis[1] that light-activated chlorophyll transfers electrons to an oxidant and removes electrons from water. There is a very close correspondence of the chlorophyll absorption bands with the emission lines of electronically excited states of the Mg atom and the Mg^+ ion in the visible and near ultraviolet region, and this was interpreted as evidence that the actual site of initial electron loss by chlorophyll is at the Mg atom.[1] The near infrared spectrum of chlorophyll has been re-examined and a mild absorption peak at around 8750 A, corresponding to Mg's only important line in the infrared at 8807 A, has been observed. This peak corresponds in the free Mg atom to the singlet-singlet transition $3p\rightarrow 3d$, and it is shown that chlorophyll's main red peak at 6600 A corresponds to the 6545 A calculated from the term value (15 266 cm^{-1}) for the transition of the Mg atom from a $3d$ singlet state to infinity, therefore representing photoionization of the chlorophyll molecule. The theory leads us to predict new absorption bands for chlorophyll at 2680, 2450, 2330, 1980, 1740, 1320, and 1230 A, and an ionization potential of 1.89 v.

* To be given at the end of Session S if the Chairman rules that time permits.
[1] L. S. Levitt, Science **118**, 696 (1953) and **120**, 33 (1954); J. Chem. Phys. **28**, 515 (1958); Experientia **15**, 16 (1959).

SU11. Angular Momentum in Classical Mechanics. H. C. CORBEN, *Ramo-Wooldridge Research Laboratory.**—According to relativistic classical mechanics, if a particle is moving with its spin parallel or antiparallel to its velocity, the magnitude of the spin angular momentum $|\boldsymbol{\sigma}|$ is equal to that in the rest system, σ_0, but if $\boldsymbol{\sigma}$ is normal to its velocity $|\boldsymbol{\sigma}|=\sigma_0(1-\beta^2)^{-\frac{1}{2}}$. The act of bringing a particle of magnetic moment $\boldsymbol{\mu}$ up to a distance r from a fixed charge puts $(Ze\boldsymbol{\mu}/cr)$ units of angular momentum into the electromagnetic field if $\mathbf{r}\cdot\boldsymbol{\mu}=0$ and zero units if $\mathbf{r}\times\boldsymbol{\mu}=0$, so that for general motion in a Coulomb field $\mathbf{l}+\boldsymbol{\sigma}$ is not a constant of the motion. If radiation damping is neglected either the particle moves on the surface of a sphere or the electric moment is normal to the radius vector. Although in general the magnetic moment increases with velocity, the precession frequency in a uniform magnetic field

decreases as the velocity increases. Special cases of the classical motion described by the equation of motion

$$\left(\frac{\partial v}{\partial t}\right)_i = \frac{e}{mc^2} f_{ij} v_j + \frac{g}{2mc^2} \sigma_{kl} \partial_i f_{kl} - \frac{2}{3} \frac{e^2}{mc^2} \left(\frac{\partial^2 v}{\partial t^2}\right)_i.$$

* To be given at the end of Session U if the Chairman rules that time permits.

SU12. Fundamentals of a Completely Deterministic Quantum Mechanics.* J. P. WESLEY, *University of California, Livermore.*†—In addition to rejecting the indeterminacy interpretation of the Heisenberg uncertainty principle, as is done by de Broglie and Bohn, it is possible to resolve many further difficulties by relinquishing the probability amplitude interpretation of ψ. Assuming that the classical four-vector momentum is given as some function of ψ and by assuming that the Klein-Gordon equation (divided by ψ) is a conservation of energy equation, it is possible to obtain the momentum as a definite function of ψ. The momentum equations are first order differential equations which may be integrated to obtain the descrete trajectory. The three eigenvalues and the three constants of integration yield the requisite six constants of the motion, or initial conditions, which determine the motion for all time. The apparent probabilistic behavior of a collection of particles is ascribed to a distribution over unknown initial conditions. Because the probability distribution predicted by this theory is not $\psi\psi^*$, it is hoped that eventually an experiment can be devised to distinguish between this theory and traditional quantum mechanical theory.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

† To be given at the end of Session U if the Chairman rules that time permits.

SU13. Possible Dependence of the Velocity of Light on Wavelength *in vacuo*. LEONARD S. LEVITT, *Stevens Institute of Technology.**—If c_0 is the maximum velocity of electromagnetic radiation through space, and c is any possible slightly smaller velocity for such radiation then the uncertainty in the momentum of a photon of wavelength λ is $\Delta p = (h/\lambda)[(c_0/c) - (c/c_0)]$. If the uncertainty in position of the photon is Δx, then application of the uncertainty relation gives $c/c_0 \leq [1 + (\lambda/2\pi\Delta x)^2]^{\frac{1}{2}} - (\lambda/2\pi\Delta x)$. For large Δx this is simplified to $c = c_0(1 - \lambda/2\pi\Delta x) \simeq c_0/(1 + \lambda/2\pi\Delta x)$, and it is seen that the velocity would decrease linearly with increasing wavelength. However, Δx is not infinite, since a photon must be somewhere within the universe, and hence $\Delta x_{max} = R$, where R is the radius of the universe. Under this condition the correction to c_0 is, of course, extremely negligible (on the order of 1 in 10^{33} for visible light), but R may once have been much smaller and the correction correspondingly larger. In an expanding universe the uncertainty in the velocity of light would vary inversely as the age, τ, of the universe: $\Delta c = \lambda/\pi\tau$. Much smaller values of Δx might be possible for "confined" photons, as perhaps, within the *hohlraum* of a blackbody.

* To be given at the end of Session U if the Chairman rules that time permits.

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Repeat of the Preliminary Announcement of the 1959 Thanksgiving Meeting in Cleveland

The 1959 Thanksgiving Meeting of The American Physical Society is to be held at the Case Institute of Technology in Cleveland on Friday and Saturday, November 27 and 28. The Department of Physics will be our host and all general requests for information should be directed to Professor Leonard O. Olsen who is the Chairman of the Local Committee.

The Wade Park Manor Hotel (East 107th Street at Chester Avenue) has been selected as the headquarters hotel. It is five minutes' walk from Case Institute, and its rates are $7 to $13 for a single and $10.50 to $17 for a double room. If you wish to stay at the hotel, write to it directly, and the sooner the better.

Announcement of the 1959 Meeting of the Division of Fluid Dynamics

The Division of Fluid Dynamics of The American Physical Society will again hold its annual Divisional Meeting this year over the three days preceding Thanksgiving, namely, November 23, 24, and 25. The meeting will be on the campus of the University of Michigan, Ann Arbor, and will be devoted to various aspects of the physics of fluids, including superfluidity, hydrodynamics, magnetofluid dynamics, rarefied gas dynamics, turbulence and boundary layer phenomena, and high-speed and high-temperature fluid flows. The scope of the Division of Fluid Dynamics covers kinetic theory, statistical mechanics, structure and dynamics of gases, liquids, and other fluids. Abstracts of contributed papers of not over 200 words, prepared in accordance with the rules printed in this Bulletin, should be sent in duplicate to the Secretary of the Division, Raymond J. Emrich, Department of Physics, Lehigh University, Bethlehem, Pennsylvania. Deadline date for receipt of abstracts is October 9, 1959. Room reservations should be made individually by writing to the Michigan Union, Ann Arbor, Michigan, and mentioning the meeting of the Division of the Society.

1959 Gaseous Electronics Conference

The twelfth annual Gaseous Electronics Conference will be held at Washington, D. C., in the National Bureau of Standards, on October 14, 15, and 16, 1959. Invited papers at this Conference will center around "Collisions between Atomic Systems." Any member of the Society who desires more detailed information must write to the Secretary of the Conference, who is Dr. L. M. Branscomb, National Bureau of Standards, Washington 25, D. C. Abstracts of contributed papers may be sent to Dr. Branscomb (*not to the Secretary of the Society!*) and must reach him not later than August 29. Take note that it is the prerogative of the management of the Conference to accept or decline contributed papers that are offered.

1959 Conference on Magnetism and Magnetic Materials

Members of the Society who desire more information on this conference to be held in Detroit, November 16–20, 1959, should write to Dr. C. L. Hogan, Motorola Inc., 5005 McDowell Road, Phoenix, Arizona. A more detailed announcement of the conference is expected to be published in the next issue of the *Bulletin*.

1960 Conference on Reactions between Complex Nuclei

A second conference on Reactions between Complex Nuclei will be held on May 2 and 3, 1960, at Gatlinburg, Tennessee. Any member of the Society who desires more detailed information should write to Dr. Robert S. Livingston, Oak Ridge National Laboratory, Oak Ridge, Tennessee. Abstracts of contributed papers may be sent to Dr. Livingston (*not to the Secretary of the Society!*) and must reach him not later than April 2, 1960. Take note that it is the prerogative of the management of the Conference to accept or decline contributed papers that are offered.

Formation of a Division of Plasma Physics in The American Physical Society

THE formation of the Division of Plasma Physics was approved by the Council of The American Physical Society on April 29, 1959. It is one of six Divisions within the Society devoted to the study of a specialized area of Physics.

Any Fellow or Member of The American Physical Society may enroll in the Division by paying an initiation fee of $2.00. There are no additional dues for the Division. An Organizing Committee of eight members, appointed by the President of the Society, has met and is at present preparing by-laws and formulating plans which will be submitted later to the membership of the Division.

The object of the Division shall be the advancement and diffusion of knowledge regarding the physics of highly ionized gases of natural or laboratory origin—including their creation, containment, heating, and acceleration; their radiations, oscillations, and stability; their transport, collective and wave properties; *et al.*

In addition to taking part in the regular meetings of the Society, the Division plans to organize divisional meetings about once a year devoted exclusively to plasma physics. The first of these meetings is tentatively planned for sometime late in 1959. In addition, a meeting in June, 1960, is contemplated in conjunction with one of the regular APS meetings.

Members of The American Physical Society who wish to enroll in this Division must fill out and mail the form hereunder, not forgetting the check for $2.00.

A meeting of the Division has been arranged for December 3, 4, and possibly 5 at the Naval Postgraduate School in Monterey, California. Further information may be obtained from Dr. Frederic H. Coensgen, P. O. Box 808, Livermore, California.

Melvin B. Gottlieb, *Chairman*
Marshall Rosenbluth, *Vice Chairman*
Alan C. Kolb, *Secretary-Treasurer*
Frederic H. Coensgen
Henry Hurwitz, Jr.
Wulf B. Kunkel
James A. Phillips
Albert Simon

American Institute of Physics
335 East 45 Street
New York 17, New York

Gentlemen:

I am a member of The American Physical Society. Please record me as a member of its Division of Plasma Physics and inform the Organizing Committee of the Division. Herewith enclosed is my check (made out to American Institute of Physics) for two dollars as initiation fee.

Yours truly,

Name .....

Address .....

.....

Proceedings of the American Physical Society

Minutes of the 1958 Winter Meeting on the West Coast Held at the University of California, Los Angeles, California, December 29, 30, and 31, 1958

THE 1958 Winter Meeting on the West Coast of the American Physical Society was held at Los Angeles, California, on Monday, Tuesday, and Wednesday, December 29, 30, and 31. This is the fourth year in a row that we have enjoyed perfect weather at our Winter Meetings. The sky was bright and clear, and the weather was balmy, so we were able to enjoy the excellent outdoor facilities which were made available for us by our hosts. The sessions were held in auditoriums surrounding a large open court that housed the registration area. Most of the extra-session conversations took place in this court, where coffee was served continually throughout the meetings. The great fire in Topanga Canyon New Year's Eve marred the end of the meetings for those who were to attend parties in the Malibu area. For others, it provided a typical Southern California climax.

There were 34 invited papers and 128 contributed papers, and again very few of the contributed papers were read by title. This is the first meeting in the recollection of the Local Secretary that an invited paper was not given (paper D2). The all-day session on the second day of the meeting, devoted to high-energy physics, was very well attended and was generally deemed successful. This policy on the arrangement of the invited papers will undoubtedly be followed more and more at the meetings on the West Coast. The total paid registration was 750, and the banquet attendance was just 250. Four of the major research companies in the Los Angeles and San Diego area contributed two cocktail parties held for members of the Society just before the banquet, and this is the third successive year that we have been able to serve wine at the dinner as well. The presiding officer at the banquet was Professor J. W. Beams, the President of the American Physical Society. The principal speaker was Professor H. C. Urey, who spoke on "Some Comments on Present Day Physics." The Society was welcomed to the campus of the university by Chancellor Raymond B. Allen.

The local chairman for this meeting was Professor J. R. Richardson, to whom we owe a great deal of thanks.

W. A. Nierenberg
Local Secretary for the Pacific Coast
Department of Physics
University of California
Berkeley 4, California

Errata Pertaining to Abstract L14 of the 1958 Los Angeles Bulletin (Series II, Vol. 3, No. 8)

L14, by Shang Yi Ch'en and Allen Smith. In the third sentence, instead of "1.23 and 1.10 A," read "1.23 and 1.10 for A." In the last sentence, instead of "respectively 0.07 and 0.15," read "0.07."

Minutes of the Meeting of the Southeastern Section Held at Loyola University, New Orleans, Louisiana, April 9, 10, and 11, 1959

THE twenty-fifth meeting of the Southeastern Section of the American Physical Society, held at Loyola University on April 9, 10, and 11, 1959, was attended by about 375 physicists from the region. The arrangements at Loyola University were made by F. A. Benedetto; the program was planned by another committee chaired by Paul Shearin. The program of 18 invited and 60 contributed papers appears below. Titles of one invited demonstration lecture and 10 additional papers related to physics teaching are recorded in the *American Journal of Physics*. The dinner address was given by Alvin M. Weinberg, Oak Ridge National Laboratory. During the meeting the Section chose Gatlinburg, Tennessee, as the site of its 1960 meeting on April 7, 8, and 9. The Section also elected the following as its officers for 1959–60: Chairman—L. W. Cochran, University

of Kentucky; Vice-chairman—H. W. Lewis, Duke University; Secretary—Howard Carr, Alabama Polytechnic Institute; Treasurer—Myron McCay, University of Chattanooga; Executive Committeeman—Max Goodrich, Louisiana State University. Vincent Parker, Louisiana State University, is the retiring Chairman.

HOWARD CARR, *Secretary*
Southeastern Section
American Physical Society

Instrumentation, General Physics

(KARL Z. MORGAN presiding)

Invited Paper

A1. Neutron Diffraction Research. M. K. WILKINSON, *Oak Ridge, National Laboratory.*

Contributed Papers

A2. Neutron Diffraction Investigations of the Ferromagnetic Ordering in HoN. H. R. CHILD, M. K. WILKINSON, E. O. WOLLAN, AND J. W. CABLE, *Oak Ridge National Laboratory.*—Neutron diffraction investigations have been performed on HoN at temperatures down to 1.25°K to determine the existence of magnetic ordering in this compound at low temperatures. At the high temperatures the normal nuclear reflections are superimposed on a very high paramagnetic diffuse scattering, but the diffraction patterns in the liquid helium temperature region show strong magnetic reflections which indicate a simple ferromagnetic ordering of the atomic magnetic moments. Measurements of the magnetic intensities as a function of temperature predict a Curie temperature in the neighborhood of 20°K. Preliminary calculations based on the coherent magnetic intensities and the difference in diffuse scattering above and below the Curie point give a value of about 7.5-Bohr magnetons for the atomic magnetic moments in the ordered ferromagnetic lattice. This value is considerably lower than the moment calculated for the free Ho^{+3} ion (10.6 Bohr magnetons), but the diffraction patterns at low temperatures indicate an appreciable amount of inelastic scattering which has not been analyzed. The high symmetry of the crystal structure of this compound (NaCl structure) permits a good determination of the paramagnetic scattering and the corresponding magnetic form factor associated with the spin and orbital contributions to the atomic magnetic moments of 4 *f* electrons in this ion.

A3. ac Measurements of Electron Flux in Media Irradiated by X-Rays. R. A. FINSTON, W. G. STONE,* H. H. HUBBELL, JR., AND R. D. BIRKHOFF, *Oak Ridge National Laboratory.*—The electron flux within a medium under *x*-irradiation is determined by measuring the derivatives of the current-voltage curve of the electrons emitted by two closely spaced parallel plates in vacuum. Previously the derivatives were evaluated directly from the curve.[1] Now considerably increased accuracy, sensitivity, and electron energy range are obtained by an ac method. Two signals of equal amplitude and frequencies 300 and 324 cps modulate the dc plate voltage. The beat frequency amplitude is proportional to the second derivative. First derivatives were obtained by integrating the second derivatives, and both were used to determine the flux.[2] Fluxes in copper and aluminum have been measured out to an energy of about 50 -electron v. The spectra follow the inverse square dependence on energy noted before[3] out to about 20-electron v where they begin to fall off more rapidly. The total yield is proportional to the x-ray energy absorbed in the surface of the plates as calculated from mass absorption coefficients for x-ray energies from 30 kv to 200 kv.

* Now at Redstone Arsenal.
[1] Birkhoff, Nelson, Hubbell, Jr., and Ritchie, Health Phys. **1**, 219 (1958).
[2] R. D. Birkhoff, Bull. Am. Phys. Soc. Ser. II, **3**, 300 (1958).
[3] Nelson, Birkhoff, Ritchie, and Hubbell, Jr., ORNL-2521.

A4. A Sensitive Gamma-Ray Dosimeter.* B. L. BLANKS, AND K. H. ROHRER, *Emory University.*—A sensitive gamma-ray dosimeter for use both in phantom material and in body cavities is described. A one-quarter in.-diam lucite light pipe assures maximum light transfer from a one-quarter in.-diam anthracene scintillator to a 1P21 photomultiplier tube. Errors due to the scintillation of the lucite light pipe, and to the current generated by direct gamma radiation of the photomultiplier tube, are cancelled by the use of a light chopper between the anthracene and the light pipe. The pulse amplifier and detection circuits are also outlined. The instrument is suitable for dosimetry over a range from 100 mr/hr to 100 r/min. The maximum sensitivity of this instrument is about 10 times better than that of systems which use a hollow aluminum tube for a light pipe.

* This work was supported by the U. S. Atomic Energy Commission.

A5. Beta Scintillation Spectrometry. L. K. AKERS AND D. L. COFFEY,* *Oak Ridge Institute of Nuclear Studies.*—The wide spread use of gamma scintillation spectrometers makes feasible the use of scintillation spectrometry for the identification and measurement of beta activity. The short-resolving time, high-counting efficiency, long life, and low cost of the beta detector make it desirable for many applications. The use of this method in low-level counting and in beta energy determinations will be discussed.

* Now at Oak Ridge National Laboratory.

A6. Total Radiation Measurements on a High-Energy Vacuum Carbon Arc. J. F. POTTS, JR., *Oak Ridge National Laboratory,* AND C. H. WEAVER, *University of Tennessee.*—This paper described the design and use of a circular foil thermoelectric radiometer for diagnostic studies on a high-energy vacuum carbon arc collimated by a magnetic field. Data are presented illustrating the variation of total radiation from the arc with axial position, interposition of various filters, arc current, and magnetic field strength. The arc column dissipates most of its energy in the form of electromagnetic radiation. The interposition of filters between the arc and radiometer establishes that at least 95% of the arc

radiation is in the wavelength region below 2000 A. The radiation per unit length (for an arc of 3 to 6 in. in length) decreases from anode to cathode, the value near the cathode being 30% lower than near the anode. The total radiation from the arc increases with arc current; an inflection point occurring at 200 amps. The total arc radiation increases linearly with magnetic field strength in a uniform magnetic field.

A7. Radiation of Photons from Foils Bombarded by Charged Particles. R. H. RITCHIE AND H. B. ELDRIDGE, *Oak Ridge National Laboratory.*—Optical reflection experiments have been of great value in the study of electronic states in solids. Ferrell has suggested[1] that photon emission by metal foils irradiated by charged particles should occur at ω_p, the characteristic plasma frequency of the conduction electrons. A fast electron supplies a nearly white electromagnetic spectrum of incident photons and selective reflection may occur at the frequency ω_p. This reflection may be treated using the formulation of Frank and Ginsburg[2] for the emission of transition radiation from foils bombarded by normally incident charged particles. Employing the classical dielectric constant of a metal it is found that the total frequency distribution of emitted photons varies as $1/\omega$ for $\omega \ll \omega_p$. Low-energy photons are emitted primarily at grazing angles relative to the foil surface, while photons of frequency $\sim\omega_p$ are emitted around the normal to the foil. Experiments to detect the characteristic radiation from metal foils should be designed to take account of this characteristic of the angular distribution.

[1] R. A. Ferrell, Phys. Rev. 111, 1214 (1958).
[2] I. Frank and V. Ginsburg, J. Phys., U.S.S.R. 9, 353 (1945).

A8. Sputtering of Metals by Various Ions. O. C. YONTS, *Oak Ridge National Laboratory.*—Sputtering ratios (atoms out/ion in) of copper have been determined in the energy range 10–40 kev with helium and deuterium. With argon ions, the energy range is 5–60 kev. Additional bombardments of copper have been made with N^+, Ne^+, Cu^+, Kr^+, and U^+, all at 30 kev. Sputtering ratios of aluminum by helium ions have been determined over a limited energy range. Some measurements have been made on molybdenum and tantalum at 30 kev using A^+ ions. Some preliminary values for the energy of the sputtered copper atoms have been obtained. Sputtering ratios vary from a low of 0.02 for He^+ on aluminum at 20 kev to a high of 9.2 for A^+ on copper at 40 kev.

A9. A Simple Low-Level dc Amplifier for Thermocouple Output Voltages. R. H. ROHRER AND J. W. CHIDSEY, *Emory University.*—A preamplifier for output voltages of differential thermocouples using a laboratory galvanometer and CdS photocells has been constructed. The device will deliver 5 mv to a recorder with input voltages as low as 20 mv. With simple modifications gains as high as 30 000 may be obtained with good stability. Adequate feedback is incorporated to avoid instability due to photocell misbehavior, and the proper choice of reactances is sufficient to prevent oscillation. Advantages of the circuit include the simplicity of the design, the use of standard laboratory components, and low cost compared with electronic amplifiers designed for the same purpose.

A10. Electron Spin Resonance Studies of Chemical Protection from Radiation Damage.* WALTER GORDY AND ICHIRO MIYAGAWA, *Duke University.*—Certain chemical agents are known to reduce markedly radiation effects in animals. In the hope of obtaining information on their protective mechanisms we are making observations of their effects on irradiation induced electron spin resonance patterns in proteins, nucleic acids, and other biochemicals. We find that quantities of 10% or less by weight of cysteine dissolved in rat liver, silk, casein, egg albumin, and zein alter completely the spin resonance patterns produced by x- or γ-irradiation and in rat liver and zein produce a relatively sharp singlet resonance not characteristic of either the pure protein or the pure cysteine. In contrast, no detectable effects were observed for similar amounts of cysteine in the amino acids and simple peptides investigated so far. Blood fibroin and DNA showed no effect, and RNA gave only a weak, inconclusive effect. The results so far obtained suggest that the protective agents form a complex with certain proteins or other large molecules which they protect from damage by absorbing the impulse or charge which in some manner is transferred to them. Other chemical protectors are being studied.

* This research was supported by the Office of Ordnance Research, Department of the Army.

A11. Electrical Polarization Induced in Electrolyte Saturated Earth Samples. JOHN H. HENKEL, *University of Georgia.*—The phenomenon of electrical polarization induced in electrolyte saturated earth samples by electric currents is similar in many respects to the phenomenon of the anomalous absorption of sound by gases; i.e., (1) there is an optimum frequency and electrolyte concentration for which the induced polarization is a maximum, (2) the dependence of induced polarization upon clay content in the soil sample is very similar to the dependence of the sound absorption coefficient in air upon humidity. Relaxation effects are introduced by assuming that there is a second state for the electrolyte in the soil sample and that the rate of transfer of electrolyte from one state to another is proportional to the effective concentration differences.

A12. Sound Absorption in Ethylene (C_2H_4). WILLIAM B. PHILLIPS AND JOSEPH W. SLOAN, *Vanderbilt University* (introduced by Robert Lagemann).—The absorption of compressional waves in ethylene was measured by the sound-tube method in the range of 270 kc/atmos to 2160 kc/atmos. Subtraction of the classical and tube-effect absorption yielded the internal absorption of the gas. The maximum internal absorption was found to occur at 875 kc/atmos at 29°C, corresponding to a vibrational relaxation time of 2.44×10^{-7} sec. Some special features of the experimental apparatus will be discussed.

Nuclear Physics

(JOSEPH L. FOWLER presiding)

Contributed Papers

B1. Investigations of Atmospheric Cosmic Ray Neutrons. R. D. EDGE, *University of South Carolina.*—The Szilard Chalmers reaction employing an aqueous solution of sodium permanganate solution has been found to have definite advantages as a detector for cosmic ray neutrons. Measurements made above Canberra, Australia (The Australian National University) showed an altitude dependence of $e^{(-x/160)}$ where x is the atmospheric depth in gm/cm². The slow

neutron flux just below a water surface was determined by a similar method. Preliminary experiments to determine the cosmic ray neutron flux just above the earth's surface will be described.

B2. Low Energy Neutron Resonance in Lanthanum. J. A. HARVEY, R. C. BLOCK, AND G. G. SLAUGHTER, *Oak Ridge National Laboratory.*—Transmission measurements have been made with the ORNL high-intensity neutron time-of-flight spectrometer upon thick samples of lanthanum in search of weak resonances in this magic neutron number nuclide. In addition to the strong resonance at 73 ev, three very weak resonances at 0.752, 3.06, and 21.3 ev were observed. Additional transmission measurements were made upon a 359 mg La^{138} sample enriched to 0.59% in La^{138}, and the resonance at 3.06 ev was definitely assigned to La^{138} (which is present to 0.089% in natural lanthanum). The resonance at 0.752 ev was not observed in the La^{138} sample and is tentatively assigned to La^{139}. The radiation width of this resonance is only 0.055 ± 0.010 ev, which is considerably smaller than that of the 73 ev resonance in La^{139}. This resonance at 0.752 ev, when assigned to La^{139}, has a neutron width of only 8×10^{-8} ev and, hence, is very probably not a *s*-wave resonance. Thick samples of other nuclides, such as praseodymium, are being investigated in search of very weak resonances not previously observed.

B3. High-Output Level Time-to-Voltage Converter. D. G. MAEDER, *Oak Ridge National Laboratory.*—A new time-of-flight measuring apparatus was designed for neutron experiments with a pulsed Van de Graaff generator. It differs from conventional time-to-amplitude converters in that it produces a dc output large enough to be fed directly into a multichannel sorting device. Separate amplifiers and pulse stretchers between the time conversion and the voltage measurement are thus eliminated. The converter itself has the features of a precision pulse stretcher, and it cancels the stretching period for those events whose delay time exceeds a certain T_{max}. For such events, deadtime is reduced to $(T_{max}+T_{reset})$, whereas the conventional arrangement would be overloaded. Since practically all operations are performed by dc coupled logical circuitry, time conversion factor and stretching period may be chosen arbitrarily in a wide range. Presently available conversion factors of 3, 6, 12, 24, and 48 mμsec per volt, with the output scan set at 67 v, correspond to a selection of T_{max} from 200 mμsec to 3.2 μsec. Resolution is 2.5 mμsec full width at half maximum, as tested with Na^{22} annihilation coincidences using fast scintillators, independent on the length of delay cable inserted in the "Stop" channel up to at least 120 mμsec. Factors governing linearity, long term stability, maximum useful stretching time, compensation of the "walk" effect, and behavior at >10 000 counts/sec will be discussed.

B4. Neutron Radiative Capture Cross Sections from 10 to 150 kev. J. H. GIBBONS, R. L. MACKLIN, P. D. MILLER, AND J. H. NEILER, *Oak Ridge National Laboratory.*—The ORNL 3-Mv pulsed Van de Graaff has been used with a large liquid scintillator[1] to study neutron capture cross sections as a function of neutron flight time. The measurement of the absolute cross section was determined earlier at 29 and 63 kev.[2] Relative values were normalized to γ-rays from $B^{10}(n,\alpha\gamma)Li^7$, assuming a 1/v behavior for this cross section.[3] The slope of the cross section results ($\sigma\sim E^{-3/4}$ on the average) in the energy range 30–70 kev is in good agreement with the "threshold" measurements at 29 and 63 kev. Results will be presented on the following heavier elements: Ho, Tb, Ta, Pt, Pd, Ag, Au, Nb, In, Sb. Cross section departure from a simple power dependence on energy is particularly noticeable for Pt, Ag, and Au.

[1] Neiler, Macklin, Gibbons, and Miller, Bull. Am. Phys. Soc. Ser. II, **4**, 43 (1959).
[2] Macklin, Neiler, Gibbons, and Miller, Bull. Am. Phys. Soc. Ser. II, **4**, 43 (1959).
[3] J. H. Gibbons and R. L. Macklin, (to be published).

B5. Scattering of Neutrons from Beryllium. J. L. FOWLER AND H. O. COHN, *Oak Ridge National Laboratory.*—Further measurements of the differential scattering of neutrons from Be with an intense neutron source[1] have improved the accuracy of the cross sections reported previously.[2] In the energy range 1.9–4.6 Mev, the neutron total cross section of Be has also been measured with 25 kev resolution. Agreement with the data of Bockelman *et al.*[3] in the range of energies common to both sets of data is good providing both are corrected for inscattering by use of the differential measurements. As explained previously,[2] a qualitative analysis of the differential curves leads to an assignment of $J=2+$ for the quantum parameters of the broad level at 3.0 Mev. A more detailed analysis indicates that there is superimposed on this broad resonance a somewhat narrower *d* level. This information and the magnitude of the total cross section gives tentative spin and parity assignments of 4− for this latter level. A phase shift analysis of the scattering data will be discussed.

[1] A helium-cooled, double foil, $T(p,n)$ gas cell developed by R. W. Lamphere.
[2] J. L. Fowler and H. O. Cohn, Bull. Am. Phys. Soc. Ser. II, **3**, 305 (1958).
[3] Bockelman, Miller, Adair, and Barschall, Phys. Rev. **84**, 69 (1951).

B6. Cross Section for the $Al^{27}(n,\alpha)Na^{24}$ Reaction as a Function of Neutron Energy. H. W. SCHMITT AND J. HALPERIN, *Oak Ridge National Laboratory.*—The $Al^{27}(n,\alpha)Na^{24}$ cross section has been measured as a function of neutron energy from 6.2 to 8.3 Mev and at 14.8 Mev. The measurement was made relative to the fission cross section of U^{238} using samples of aluminum mounted adjacent to and concentric with a thin deposit (∼100 μg/cm²) of U^{238}. The number of $Al^{27}(n,\alpha)$ events was determined by counting γ rays from the residual radioactive Na^{24} nuclei. The γ-ray detector was a NaI(Tl) crystal whose efficiency was measured in auxiliary experiments using coincidence techniques and 4π-beta-counting. The number of neutrons incident on the aluminum sample was determined by counting fission fragments from the U^{238} deposit in a 2π ionization chamber. While a number of peaks appear in the cross section *vs* energy curve, there is a general increase in cross section with increasing neutron energy, from about 3 millibarns at 6.2 Mev to about 46 millibarns at 8.3 Mev. The measured cross section at 14.8 Mev is 117 ± 8 millibarns.

B7. 60° Deflection, Uniform Field, Double-Focusing Reaction Product Magnet. H. B. WILLARD AND J. K. BAIR, *Oak Ridge National Laboratory.*—A reaction product magnetic analyzer has been constructed[1] which employs a uniform field and fringe field focusing to achieve a reasonably large solid angle. Utilizing Cross' notation,[2] the design parameters were $f=15^n$, $\theta=60°$, $1'=1$, $1''=2.06$, $\epsilon_1=56°\,34'$, $\epsilon_2=-32°\,16'$, gap $=0.75''$, $\alpha_{max}=\pm5.5°$, $\omega_{max}=\pm1.2°$. The boundaries and locations of object and image distances were corrected for the effect due to the fringe field.[3] Resolution measurements, taken with a thick gold target, a one-mm square object size, and the full solid angle of the magnet, reached an optimum value of 1/500 in momentum for an image width of 1.5 mm in the bending plane. The theoretical maximum solid angle of 0.006 steradians has not yet been checked experimentally. This magnet can bend 17.6-Mev protons, and is variable in angle from 15° to 145°. Preliminary data on the elastic scattering of protons by Si^{28} will be presented.

[1] Built by Pacific Electric Motor Corporation, Oakland, California.
[2] W. G. Cross, Rev. Sci. Instr. **22**, 717 (1951).
[3] K. T. Bainbridge, *Experimental Nuclear Physics* (John Wiley & Sons, Inc., New York, 1953), Part V, Vol. I.

B8. 22-Mev Proton Elastic Scattering from Ni^{64}, Zn^{64}, and Cu. C. B. FULMER, *Oak Ridge National Laboratory.*—It has been suggested[1] that the real nuclear potential well depth, *V*, for nucleon-nucleus scattering depends on the parameter

$(N\text{-}Z)/A$; i.e., $V=-[(V_1\pm(N\text{-}Z)/A)V_2]$ for protons and neutrons, respectively. Such a variation should manifest itself in variations in the angular distributions of nucleons elastically scattered by isobars. In particular the positions of the maxima and minima, which depend largely on VR,[2] should vary. The external proton beam of the ORNL 86-in. Cyclotron was used in a search for these variations; an examination was made of the angular distributions of 22-Mev protons elastically scattered from Ni^{64}, Zn^{64}, and Cu. The scattered protons were detected with a NaI(Tl) scintillation detector; pulse height analysis was used. The results indicate that for 22-Mev protons (V_2/V_1) is too small for the $(N\text{-}Z)/A$ dependence of V to produce observable effects in experiments of this kind.

[1] A. E. S. Green and P. C. Sood, Phys. Rev. 111, 1147 (1958).
[2] A. E. S. Green, private communication.

B9. Energy Dependence of N^{14}-C^{12} Elastic Scattering. M. L. HALBERT, C. E. HUNTING, AND A. ZUCKER, *Oak Ridge National Laboratory.*—The 28-Mev N^{3+} beam from the ORNL 63-in. cyclotron has been used to study the elastic scattering of N^{14} by C^{12}. To distinguish elastic scattering from other events, the scattered and recoil particles were detected in coincidence by CsI(Tl) scintillation counters. The differential cross section was measured at full beam energy (about 27.7-Mev mean energy in the target) and with the energy degraded by a nickel absorber (about 24.4-Mev mean energy). At the lower energy, the magnitude of the cross section is larger by a factor of approximately two. The angular distributions at small angles are generally similar. At large angles maxima and minima are observed, but at different angles for the two energies.

B10. Nuclear Spin of I^{132}. J. E. SHERWOOD, S. J. OVENSHINE, AND G. W. PARKER, *Oak Ridge National Laboratory.*—The nuclear spin of 2.3-hr I^{132} has been determined by the atomic beam magnetic resonance method. The isotope was prepared by irradiating 200 mg of aluminum-clad U^{235} in a thermal neutron flux of $10^{14}/cm^2$ sec for 10 days. After three days, the sample was heated with NaI first in air and then in vacuo, whereupon elemental I^{127}, I^{131}, and I^{132} distilled off. (The 2.3-hr I^{132} activity is maintained by decay of 77-hr fission product Te^{132}.) A conventional Rabi-type experiment was then performed with the detector so adjusted as not to count I^{131}. Frequencies corresponding to spins 6, 5, 4, 3, 2, and 1 were applied and flop was clearly observed at spin 4. The process was then repeated in the reverse order and flop was again observed at spin 4. This result appears consistent with presently accepted decay schemes.

Invited Paper

B11. Study of the Beta Decay Interaction by Recoil Experiments. CLELAND H. JOHNSON, *Oak Ridge National Laboratory.*

Symposium on High-Energy Accelerators

(ROBERT S. LIVINGSTON presiding)

C1. Brookhaven 25-Gev Accelerator. JOHN H. BLEWETT, *Brookhaven National Laboratory.*

C2. Experimental Facilities for the Princeton-Pennsylvania 3-Bev Synchrotron. GERALD K. O'NEILL, *Princeton University.*

C3. Progress Report on the Southern Regional Accelerator. T. A. WELTON, *Oak Ridge National Laboratories.*

C4. High-Energy Experiment with the Duke Liquid Helium Bubble Chamber. HANS O. COHN, *Oak Ridge National Laboratory.*

Theoretical Physics

(M. E. ROSE presiding)

Invited Papers

D1. Perturbation Theory Approach to the Nuclear Many-Body Problem. J. S. LEVINGER, *Louisiana State University.*

D2. Superfluidity in Fermion Systems. LEON N. COOPER, *Brown University.*

Contributed Papers

D3. Cluster Expansions and Ground State of Bosons with Repulsive Interactions. V. H. SMITH AND H. A. GERSCH, *Georgia Institute of Technology* (introduced by L. D. Wyly, Jr.).—The properties of a Bose system of particles with repulsive interactions has previously been treated using perturbation theory in the formalism of second quantization.[1] The same problem has also been considered by dealing with the wave function in configuration space, using the theory of cluster expansions.[2] Here, variation with respect to a parameter in a trial function for the ground state has been shown to yield a ground state energy close to the exact asymptotic expressions obtained from perturbation theory. We have treated the cluster expansion formalism so that it is completely equivalent to the perturbation theory method in the approximation of pair excitations. For hard spheres, the variational problem yields the same ground state wave function and energy as previously obtained from perturbation theory.

[1] Lee, Huang, and Yang, Phys. Rev. 106, 1135 (1957).
[2] F. Iwamoto and M. Yamada, Progr. Theoret. Phys. (Kyoto) 17, 543 (1957).

D4. A possible Unified Phenomenological Description of Nuclear Gross Structure.* P. J. WYATT,† J. WILLS,‡ AND A. E. S. GREEN,† *Florida State University.*—A unified description of the gross structure of neutron bound states and neutron-nuclear elastic scattering is attempted. Non-local diffuse boundary IPM potentials are utilized with the hope of having the potential parameters no longer explicitly dependent upon energy. The calculations have been carried out with the aid of the two IBM-704 codes. One code (by P.J.W.) yields predictions as to angular distributions and polarizations, total cross-sections and non-elastic cross-sections in phenomenological potentials. The second code (by J.W.), which is an adaptation of an earlier code for the ORNL Oracle, gives the bound state eigen-values for neutrons in the corresponding potentials. In the scattering problem, an imaginary term is incorporated which in initial studies has been taken as proportional to the derivative of the real potential. Other forms are also investigated. Comparisons of experiment and theory in a number of cases will be shown.

* Work carried out at Los Alamos Scientific Laboratories, and at the Florida State University with the support of a grant from the U. S. A. E. C.
† Now at Florida State University.
‡ Los Alamos Scientific Laboratory.

D5. Bound States of O^{17}, Si^{29}, and Ca^{41}.* F. C. KHANNA AND A. E. S. GREEN, *Florida State University.*—Bound states of O^{17}, Si^{29} and Ca^{41} have been studied using a non-local, diffuse boundary potential with a spin-orbit term. The radial part of Schödinger's equation has been solved using an IBM-704 program to obtain the eigen values and the eigen functions. It is found that wave functions for $1p$ and $1d_{5/2}$ state are quite similar for all three nuclei. An attempt has also been made to obtain simple approximate analytic representations of these numerical wave-functions which could then be used for matrix element calculations. Results of initial studies will be presented.

* Work carried out at Florida State University with the aid of a grant from the U. S. Atomic Energy Commission.

D6. On Single Particle States in Diffuse Spheroidal Non-Local Potentials.* R. H. LEMMER AND A. E. S. GREEN, *Florida State University.*—The effects of spheroidal distortion on nucleon motion in a velocity dependent potential well with a diffuse boundary is investigated. The deformed level scheme and wave functions can be found numerically by standard methods from a knowledge of the energy levels and radial wave functions of the corresponding spherical well.

The numerical solutions of a velocity dependent wave equation obtained from an IBM-704 program using diffuse well shape are employed to complete the matrix elements of the deformation-perturbation. Straightforward diagonalization then gives the deformed energy eigenvalues and eigenvectors as a function of the deformation.

The well-parameter for a given nucleus, i.e., well-depth, half-radius, diffuseness, nonlocality, and spin-orbit strength, are chosen so as to represent the relevant scattering data as well as possible. Detailed calculations of the ground-state moments and inertial parameters as a function of the nuclear deformation can then be made.

Preliminary results for Si^{29} are presented and compared with existing calculations based on the Nilssen Potential.

* Work carried out at Florida State University with the aid of a grant from the U. S. Atomic Energy Commission.

D7. Evidence for Collective Excitation in Ca^{40}.* R. H. DAVIS, *Florida State University.*—In spite of the doubly closed shell structure of Ca^{40}, the interpretation of the excited states[1] of this nucleus in terms of the shell model is somewhat unsatisfactory because of the need to invoke a two-nucleon excitation to explain the O^+ first excited state and a lack of uniqueness in the assignments for higher states. The low-lying states may also be interpreted as vibrational states according to the collective model, but again the O^+ first excited state requires some refinement in the model, unless it is simply a breathing mode excitation. Evidence for collective effects in the first three states is found in the correlation between excitation energies of states observed in the elastic scattering of protons[2,3] from Ca^{40} with those observed in the inelastic proton scattering experiments.[3,4] Maxima in the inelastic scattering strength closely correspond to a recurrence of the low-lying states in Sc^{41} above a Ca^{40} core in one of its first three excited states. This correlation is simply explained if the core states are collective in character.

* Supported in part by the U. S. Air Force Office of Scientific Research.
[1] *Nuclear Level Schemes*, TID-5300, National Research Council, Washington, D. C. (June, 1955).
[2] Davis, Prosser, Spencer, Young, and Johnson, Bull. Am. Phys. Soc. Ser. II, **2**, 304 (1957).
[3] J. H. Johnson and C. M. Class, Bull. Am. Phys. Soc. Ser. II, **4**, 97 (1959).
[4] R. D. Bent and T. H. Kruse, Phys. Rev. **109**, 1240 (1958).

D8. Pseudoscalar Interaction in Nuclear β Decay. C. P. BHALLA, *University of Tennessee*, AND M. E. ROSE, *Oak Ridge National Laboratory.*—The *V-A* (vector-axial vector) theory of nuclear β decay, as proposed by Feynmann and Gell-Mann, and Sudarshan and Marshak (1958) has met with considerable success in explaining most of the experimental results. But the question of the pseudoscalar interaction in nuclear β decay has not been settled completely.[1] Following the Rose and Osborn formulation[2] of pseudoscalar interaction, the longitudinal polarization of β particles from $O \rightarrow O$ (yes) transitions has been calculated with Coulomb effects included. The two component theory of neutrino and time-reversal invariance are assumed. A numerical analysis of the theoretical results and a comparison with the measurements on Pr^{144} will be presented.

[1] Discussion in Gatlinburg Conference on Weak Interaction (1958).
[2] M. E. Rose and R. K. Osborn, Phys. Rev. **93**, 1315 (1954).

Evening Address

(VINCENT E. PARKER presiding)

E1. The Role of Semiconductors in Photosynthesis. WILLIAM A. ARNOLD, *Oak Ridge National Laboratory.*

Fusion and Plasma Physics

(WALTER GORDY presiding)

Invited Paper

H1. DCX—the Fusion Research Experiment at the Oak Ridge National Laboratory. ROBERT J. MACKIN, JR., *Oak Ridge National Laboratory.*

Contributed Papers

H2. Collision of Ionized Gas Clouds. E. G. HARRIS, *The University of Tennessee and Oak Ridge National Laboratory.*—Kahn[1] has shown that when two very low density (about one particle per cubic centimeter) gas clouds collide with very high-relative velocities (about 10^8 cm/sec) unstable plasma oscillations are more effective in destroying the ordered motion than are close collisions between the particles. Kahn neglected the temperature of the clouds. We have reconsidered the problem, taking into account the finite spread in the velocities of the particles in the clouds and also the effect of a magnetic field. A spread in velocities leads to damping of the oscillations. The magnetic field does not affect those oscillations with wave vectors along the field but does modify those oscillations with wave vector at an angle to the field. In the presence of a magnetic field the plasma oscillations can be coupled to transverse electromagnetic waves outside of the clouds. It is conjectured that this is the cause of the radio emission observed from colliding galaxies.

[1] F. D. Kahn, Revs. Modern Phys. **30**, 1069 (1958).

H3. Probe Measurements in Plasma Jets. CHARLES CASON AND T. A. BARR, JR., *Redstone Arsenal.*—Heat transfer rates to a cold body have been measured by use of a water cooled copper probe. Variation of arc power, gas, flow rate, and nozzle area ratios produced heat transfer rates from 170 to 1700 w/cm^2.

Electrical conductivity profiles of the plasma jet have been measured using the Wilson probe technique. Temperature profiles are estimated from the conductivity data using shock tube results.

H4. Spectroscopic Analyses of Argon Plasma Jets. T. G. ROBERTS, W. L. HALES, AND W. G. STONE, *Redstone Arsenal.*—The spectroscopic techniques used in determining the temperatures in an argon plasma jet are described. The plasma is produced by an electric arc heater similar to the one described in a previous paper.[1] One technique employs an iron vapor as a tracer in the plasma. The excitation temperature for the tracer is determined from two iron emission lines (3902.95 A and 4005.25 A) for which the transition probabilities and f values are known. In another technique a sodium tracer is used to locate the 4700°K isotherm. The Saha equation for the population ratio n(ion)/n(neutral) is used to determine a temperature for maximum spectral emission for neutral atoms. The same method was applied to temperature determination in an argon plasma without a tracer. The position at which the gas appears to have a temperature of 17 000°K was located using an argon line (4289.1 A).

[1] Charles Cason and T. A. Barr, Jr., Bull. Am. Phys. Soc. Ser. II, **3**, 302 (1958).

H5. Spectroscopy of a Thermonuclear System Component—Magnetically Confined, High-Current, Vacuum Carbon Arc. M. R. SKIDMORE, J. R. MCNALLY, JR., AND G. K. WERNER, *Oak Ridge National Laboratory.*—This paper will report on the spectroscopic properties of the molecular ion breakup system used at the Oak Ridge National Laboratory in its approach toward attaining a thermonuclear plasma. The breakup system, due primarily to J. S. Luce,[1] consists of a long, high-current, magnetically collimated vacuum carbon arc. We have used an ORNL-constructed Seya type vacuum spectrometer to obtain intense spectra of this arc down to 312 A and a Bausch & Lomb echelle attachment to study ordered as well as random Doppler motions. Strong spectra through C IV and O V have been observed except for neutral atom spectra which are extremely weak. Doppler slant effects[2] corresponding to ordered motion around the arc axis are pronounced and strong axial oscillations appear to exist especially toward the cathode end of the long arc. "Temperatures" are of the order of 500 000°K although the distributions are probably far from Maxwellian.

[1] J. S. Luce, *Studies of Intense Gas Discharges.* Paper UN/P-1790, Second International Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland (1958); The ORNL Thermonuclear Program, Report ORNL-2457 (1958).

[2] See, for example, J. R. McNally, Jr. and M. R. Skidmore, J. Opt. Soc. Am. **47**, 863 (1957); J. R. McNally, Jr., *ibid.* (to be published).

H6. Plasma Diagnostics in DCX by Particle Measurements. R. J. KERR AND R. A. DANDL, *Oak Ridge National Laboratory.*—Measurements of charge-exchanged neutrals from the trapped ring of hot atomic ions have been used to get information on the plasma in the DCX machine. Faraday cups, covered with Ni foils 5 to 25 μin. thick, collect the neutrals which come off tangentially from the trapped ring of high-energy ions. Transistor preamplifiers are used to amplify the current from the detector cups for oscilloscope viewing. Gating off the injected ion beam causes current to the detector cups to decay exponentially. Containment time τ is defined as the time required for this signal to decay by $1/e$. Present maxima for τ are 12 to 14 msec for protons and 1.1 to 1.3 msec for deuterons. A plot of $1/T$ as a function of pressure gives an effective charge-exchange cross section of the background gas for the ions.

Steady-state amplitudes of the charge-exchanged neutral currents show that the width of the trapped ion ring along magnetic field is a strong function of residual gas pressure. Summation of charge-exchanged neutral current over all radial surface of the plasma accounts for all the injected ions at the higher pressures, but not at lowest pressures.

H7. Gas Breakdown in High Magnetic Fields. KAY M. EOFF, STANLEY T. NOLAN, AND JOHN W. FLOWERS, *University of Florida.*—Some preliminary measurements of the time lag of breakdown have been made for various short discharge paths in air in high magnetic fields. Discharge paths of lengths of a few millimeters have been arranged in direction both along and across the magnetic field. The magnetic field is obtained by the discharge of capacitors (240 μF) into a coil of ten turns, and fields above 2×10^5 gauss can be obtained for a current half period of 25 μsec. Time lags are measured by the application of a voltage increment to the gap and synchronized with the respect to the magnetic field. Effects of the magnetic field at atmospheric pressure first become evident in the region of 50-K gauss for discharges across the field where the time lags are considerably increased for low over-voltages.

Ultraviolet and Infrared Spectroscopy

(ERNEST A. JONES presiding)

Invited Papers

I1. Infrared Spectra of Molecular Complexes. DE FOREST SMITH, *Physics Division, K-25 Laboratory.*

I2. New Developments in Infrared Instrumentation. RAYMOND R. SAWYER, *Perkin-Elmer Corporation.*

Contributed Papers

I3. Spectra of the Rare Gas Oxides.* C. DEWEY COOPER, *University of Georgia.*—When traces of oxygen are added to one atmosphere of argon, krypton, or xenon and the mixtures are excited in a discharge tube, characteristic spectra appear near the 5577 A oxygen line.[1-3] These spectra are associated with rare-gas oxygen molecules which may be formed with oxygen in the $^1S_0$ state. New bands have been found in the XeO spectrum which requires that the v'' value be increased by one in the original assignments given by Herman.[1] The XeO bands may be represented by $\nu = 20\,097 + 142v' - 9.9v'^2 + 0.1v'^3 - (360v'' - 12v''^2)$. Many of the rotational lines of these bands have been resolved, but the overlapping of bands has prevented a complete rotational analysis.

* This research was supported in part by the Geophysics Research Directorate, Air Force Cambridge Research Center.
[1] L. Herman and R. Herman, J. Phys. Radium **11**, 69 (1950).
[2] C. D. Cooper and M. Lichtenstein, Phys. Rev. **109**, 2026 (1958).
[3] E. L. Tolnas, Bull. Am. Phys. Soc. Ser. II, **4**, 67 (1959).

I4. Infrared Intensities, Bond Moments, and Bond Moment Derivatives for PF_3 and POF_3. J. L. DUNLAP* AND ERNEST A. JONES, *Vanderbilt University.*—The absolute infrared absorption intensities of the fundamental bands of PF_3 and POF_3 were determined by use of the Wilson-Wells extrapolation theorem, and the absolute value of each $\partial u/\partial Q_k$ was calculated from the corresponding intensity. Internal coordinates (r) and symmetry coordinates (R) were defined for each molecule and the sets of $\partial u/\partial Q_k$ were transformed to sets of $\partial u/\partial R_i$. In the case of PF_3, this transformation was repeated for each of several reasonable molecular potential functions. In the case of POF_3, the potential function employed was characterized by the use of diagonal terms in the Wilson F matrix. Noninteracting bond dipole moments were assumed, and equations were derived relating the $\partial u/\partial R_i$ values to the bond moments and bond moment derivatives. The solutions of these equations will be presented and will be interpreted in terms of bond structures and static dipole moments.

* Now at the Oak Ridge National Laboratory.

I5. Molecular Constants of HCOF and DCOF.* ROY F. STRATTON† AND ALVIN H. NIELSEN, *The University of Tennessee.*—Reports on the infrared grating spectra of HCOF and DCOF have been given at previous meetings.[1] Spectra were shown illustrating the hybrid appearance of the bands resulting from dipole moment changes along the least and intermediate axes of inertia for the fundamental vibrations. Analyses of bands of both molecules, mainly below 2500 cm^{-1}, have yielded the following average rotational constants in cm^{-1}: for HCOF $B'' = 0.3673$, $A'' - B'' = 2.661$; and for DCOF $B'' = 0.3649$, $A'' - B'' = 1.806$. By choosing the C−H(C−D) distance = 1.080 A and varying the C−F, and C−O distances and the FCO angle within the error limits set by the electron diffraction[2] experiment, it was possible to calculate a set of rotational constants which agree with the above experimental set within the errors of the infrared experiment. It appears that molecular parameters consistent with both electron diffraction and infrared measurements are: r(C−H or C−D) = 1.080 A, r(C−F) = 1.3428 A, r(C−O) = 1.1857 A, FCO (angle) = 122° 14′.

* Supported in part by Office of Ordnance Research, U. S. Army.
† Present address: Oak Ridge National Laboratory.
[1] R. F. Stratton and A. H. Nielsen, Bull. Am. Phys. Soc. Ser. II, **1**, 259 (1956); **2**, 285 (1957).
[2] Jones, Hedberg, and Schomaker, J. Am. Chem. Soc. **77**, 5278 (1955).

I6. Raman and Infrared Spectra of the $(BF_4)^-$ Ion. DON F. HARMON AND ERNEST A. JONES, *Vanderbilt University.*—The Raman and infrared spectra of several compounds containing the $(BF_4)^-$ ion have been studied. The infrared spectra of KBr pellets containing both solid and liquid fluoborates were measured in the region 2 to 25 μ with a Perkin-Elmer double beam spectrophotometer. Several absorption bands were observed including all of the allowed fundamentals, which showed the the isotope effect. The Raman spectra were observed for the fluoborates that were colorless liquids, and all allowed fundamental vibrations were recorded. The data were in agreement with a tetrahedral (T_d symmetry) for the $(BF_4)^-$ ion.

I7. Infrared Study of Mixtures of Zinc Chloride and Calcium Chloride with Acetic Acid, Ethyl Alcohol, and Acetone. R. J. LOVELL AND M. R. PAULSON, *The University of Tennessee.*—An infrared study of mixtures of zinc chloride and of calcium chloride with acetic acid, ethly alcohol, and acetone has been carried out in the region from 2 to 15 μ. This was done to try to determine from changes in the spectra how the halide and the solvent had associated. Addition of zinc chloride and of calcium chloride to acetic acid caused changes in O−H deformation bands and in the C−O stretching band. Addition of zinc chloride and of calcium chloride to ethyl alcohol caused changes in an O−H deformation band and in a band which is assigned to the effect of hydrogen bonding on the skeletal vibration which involves stretching of the C−O band. Addition of zinc chloride to acetone caused no changes which could not be attributed to the effects of the water of hydration in zinc chloride. Calcium chloride did not dissolve in acetone.

From these changes it would seem probable that the metal of the halide in each case has become associated with the oxygen of the hydroxyl group in acetic acid and in ethyl alcohol.

I8. Absorption Spectrum of x-Irradiated Potassium and Sodium Chlorate.* W. E. WEBB, W. G. MOULTON, AND W. B. ARD, JR., *University of Alabama.*—The absorption spectrum of x-irradiated potassium chlorate in the region from 0.2 to 15 mμ has been examined. A single strong absorption band has been found in the near ultraviolet. This band is Gaussian with the maximum absorption at a quantum energy of 2.69 ev and a half-intensity width of 0.35 ev. The transmittancy of the the crystal was found to be an exponentially decreasing function of irradiation time and independent of the time elapsed since irradiation. In fact, within the limits of our experimental error, there was no decrease in the intensity of the band several weeks after irradiation. In irradiated sodium chlorate the same band was observed, although it was much weaker and was shifted slightly toward longer wavelengths. Another band at 4.0 ev was also observed in this centered compound.

The infrared spectrum of potassium chlorate showed no change after irradiation. The conductivity and index of refraction also appear to be unaffected.

* This work sponsored by Office of Ordnance Research.

I9. Infrared Absorption Intensities of Ions in Solid Solutions. JAMES R. LAWSON, *Fisk University*, AND HENRY W. MORGAN, *Oak Ridge National Laboratory.*—The intensities of the characteristic infrared absorption bands of $CO_3^=$, $SO_4^=$, NCO^- and other polyatomic inorganic ions have been observed to show marked increases when the ion is in a dilute solution of KBr, KCl, or other alkali halides. The solid solutions were formed by fusing the salts with alkali halides and then quenching. Samples for spectroscopic analysis were subsequently prepared by the pressed disk technique. The resulting intensity increases observed suggest the possibility of quanti-

tative determination of inorganic ions at extremely low concentrations. The data obtained also provide an explanation for the presence of weak "impurity" bands found in KBr dried by fusing and freeze-dry methods. The infrared spectra of the compounds studied will be presented and intensity measurements and frequency assignments reported.

High-Energy Nuclear Physics

(ALEX E. S. GREEN presiding)

Contributed Papers

J1. Survey of Cyclotrons and Other High Energy Accelerators. FREDERICK T. HOWARD, *Oak Ridge National Laboratory.*—A recent canvas of the world's laboratories indicates a total of over 140 cyclotrons and other high energy accelerators. Verified detailed data were obtained for over 110 machines, including at least two of the 30 machines reported for eastern Europe. The vigor with which nuclear studies are being pursued is indicated by the large number of machines (50) now under construction, being designed, or subject to serious study. An examination of the data for these new machines suggests the ingenuity with which concepts of periodic magnetic field configurations are being applied to accelerator design. In the low to medium energy range the FF cyclotron is being provided with an aximuthally varying magnetic field and a choice of frequencies for the acceleration of several ions to various energies and for operation at relativistic energies. The alternating gradient principle is being used to markedly increase the energy of both proton and electron synchrotrons and of linear accelerators. Apparently no new FM cyclotrons are being developed. Some of the features of the newer machines will be reviewed.

J2. Analysis of Magnetic Field Measurements in the Electron Model Cyclotron. WILSON M. BARNES AND DONALD L. LAFFERTY, *University of Florida.*—Previous papers[1,2] have described the method used to calculate the magnet pole-face contour for a spiral-ridge electron cyclotron and the technique used to measure the resulting field. This paper describes the digital computer techniques used to analyze the field measurements, and presents an evaluation of the methods used for calculating and producing the pole-faced contour. The theoretical and experimentally-realized fields will be compared and the predicted particle dynamics in the measured field will be discussed.

[1] Elfe, Cobb, and Lafferty, Bull. Am. Phys. Soc. Ser. II, 3, 298 (1958).
[2] W. M. Barnes and D. L. Lafferty, Bull. Am. Phys. Soc. Ser. II, 3, 298 (1958).

J3. Eight-Sector AVF Electron Cyclotron. J. A. MARTIN, *Oak Ridge National Laboratory.*—A fixed-frequency electron cyclotron with a maximum energy of at least 450 kev is being built as an analogue of a proposed 850-Mev proton accelerator. The cyclotron is of the azimuthally-varying-field type with eight spiralled sectors. The radial focusing frequency, increasing throughout the acceleration, is equal to the orbital frequency at the center and reaches twice that value at final energy. Throughout acceleration the axial focusing frequency is held nearly constant at about one-fifth the orbital frequency. A high-precision requirement for the magnetic field is characteristic of machines of this type. To maintain isochronism the average magnetic field must be accurate to 1 part in 10^4; the azimuthal variation of the magnetic field at the outside of the machine must be carefully controlled to keep the axial focusing frequency within narrow limits. The methods of achieving the desired magnetic field configuration will be described. The radial and axial stability of orbits in the machine will be discussed briefly.

J4. Microscope Stage for Large Emulsions.* R. L. CHILDERS AND D. T. KING, *The University of Tennessee.*—The introduction of large emulsion stacks was based on the need to arrest and identify fast decay products.[1] The problem of distinguishing the pions among the forward fast particles emitted from stars provides a further reason. With large emulsion plates the occurrence of secondary interactions by which particles may be identified is increased. It is notable that sixty centimeters of emulsion are sufficient to stop a 400-Mev pion.

Construction of a scanning stage accommodating large plates was undertaken. The plate carrier, of dimensions 3.5×5 feet, will hold plates as large as 30 in. $\times$ 18 in. The plate carrier is supported on a rigid base plate by freely rolling steel balls. Traversing mechanisms are mounted below the base plate and attached to the plate carrier through a hole which also serves as an opening for the illuminating system. The traversing mechanism consists of sliding ways actuated by lead screws. The optical system and fine focus control are that of a slightly modified Bausch & Lomb microscope. The stage may be tilted to facilitate scanner comfort.

* Supported by the National Science Foundation.
[1] Nuovo cimento 2, 1063 (1955).

J5. Anelasticity of Multiple Pion Production in 2.7 Bev p-p Collisions.* W. M. BUGG AND D. T. KING, *The University of Tennessee.*—Measurements have been completed on 108 stars which represent possible collisions between 2.74-Bev Cosmotron protons and free protons in nuclear emulsion. Stars of this type must have an even number of charged outgoing prongs and must show no evidence of effects due to the immediate presence of nuclear matter.

Eighty-five two prong and 23 four prong events were found. The ten elastic events were separated from the other two prong events by coplanarity and polar angle requirements. From the inelastic events came 56 charged pions which were identifiable through scattering, range, and grain density measurements. The momentum and angular distribution of these particles in the center of mass system will be discussed.

There are 42 events from which a charged pion emerged and was identified. These 42 events have been analyzed as completely as possible in order to obtain information on the anelasticity of proton-proton collisions. The anelasticity of an event is defined as the ratio of the total energy in the C system of all the pions produced, to the total available energy in that system. A preliminary distribution of the anelasticity coefficient at 2.74 Bev will be presented.

* Supported by the National Science Foundation.

J6. Kinematics of Elementary Particle Reactions. HARRY C. MEYER, III, AND W. G. HOLLADAY, *Vanderbilt University.*—A procedure for finding all the elementary particle reactions that can occur with appreciable cross section has been developed by assuming that charge, the third component of isotopic spin, and the baryon number are conserved. All the final sets of two, three, and four particles that can be produced by the hyperons and anti-hyperons incident on a nucleon have

been determined. The thresholds for each of these reactions have been calculated for both the case of the target nucleon at rest and the case of the target nucleon in a nucleus. In order that the thresholds for the multistage processes may be found easily, the maximum energy that a given particle produced in a given reaction can have has been determined as a function of the energy of the incident and target particles. The maximum energy that one of the baryons, mesons, antibaryons, and anti-mesons can have when it is produced by a nucleon and by a pion incident on a nucleon at rest and in motion in a nucleus, has been calculated. Finally, it has been attempted to find the total number of reactions possible for a given set of initial particles as a function of the number of particles produced.

Invited Papers

J7. Hyperons and Hyperon Fragments. W. G. HOLLADAY, *Vanderbilt University.*

J8. Mu Mesic Atom and Molecule in Nuclear Physics. TA-YOU-WU, *National Research Council of Canada.*

Cryogenics and Nuclear Radiations

(ROBERT T. LAGEMANN presiding)

Invited Paper

M1. The Nature of the Lambda Point Transition in Liquid Helium. W. M. FAIRBANK.

Contributed Papers

M2. Pressure Dependence of de Haas van Alphen Parameters in Zinc at Liquid Helium Temperatures.* K. S. BALAIN, C. G. GRENIER, AND J. M. REYNOLDS, *Louisiana State University.*—Work previously reported[1] showed that the Ettinghausen-Nernst voltage in zinc exhibited pure de Haas van Alphen type of oscillations with no monotonic term. In the present work, this effect has been measured at different pressures at 4.2°K and it has been possible to detect with great relative accuracy the variations in the de Haas van Alphen parameters. The sample was placed in a liquid helium bomb with its hexagonal axis parallel to the applied magnetic field. The results are such that long period oscillations of 6.35×10^{-4} gauss^{-1} decreased by 1.25% when the pressure was raised from 40 to 1000 psi. This seems to contradict some previous results[2] in zinc where an increase in pressure caused an increase in period. No change in phase could be detected as was reported in Bismuth.[3]

* Supported by the Office of Ordnance Research.
[1] Bergeron, Grenier, and Reynolds, Phys. Rev. Letters, **2**, 40 (1959).
[2] Dmitrenko, Verkin, and Lazarev, Soviet Phys. JETP **35**, 329, No. 2 (1959).
[3] W. C. Overton, Jr., and Ted G. Berlincourt. Phys. Rev. **99**, 1165 (1955).

M3. Pre-Acceleration in Beta Ray Spectroscopy. W. O. OLSON, H. H. HUBBELL, JR., AND R. D. BIRKHOFF, *Oak Ridge National Laboratory.*—A double hemispherical accelerator with annular slots permitted electrons to escape into the acceptance angle of a beta spectrometer of the solenoidal homogeneous magnetic field type. The acceleration widened the momentum increment transmitted from the source and reduced counter window absorption and resolution. The departure from linearity of the Fermi plot of a thin source of Pm^{147} permitted evaluation of Geiger counter window transmission. The true momentum distribution $N(p)$ is related to the observed count rate M by $N(p)=M(I/J^2)[1+\Delta E/(T+m_0c^2)]$ where I is the spectrometer current for beta rays of energy T. J is the larger current at which M is observed for beta rays of initial energy T accelerated by ΔE. Corrected spectra showed that, with acceleration, focusing varied inversely with acceleration, focusing varied inversely with source-size. The ratio between the corrected momentum spectrum with acceleration to that without varied from unity for $\Delta E/T=0.1$ to 1.8 for $\Delta E/T=1$ for a particular ring source. Trajectory calculations suggest no distortion for the first case, but considerable rotation of the trajectories about the axis of the spectrometer in the second. Theoretically such rotations may be avoided for $\Delta E/T\geqslant 10$ for ratios of sphere radii >10.

M4. A Study of the Gamma Ray and Inner Bremsstrahlung Transitions in the Decay of Tin-113.* WILLIE E. PHILLIPS† AND JOHN I. HOPKINS,‡ *Vanderbilt University.*—A fast-slow coincidence spectrometer was used to study the decay of Sn^{113}. A 650-kev gamma ray was found in the single-channel spectrum and it was found to be in coincidence with the In K x-ray in the fast and in the slow coincidence spectra. This confirmed the existence of a 650-kev level in In^{113} fed by a weak orbital capture branching. From the relative intensities of the 257-kev gamma rays and the 650-kev gamma rays (16.4±1.3:1), it was determined that the spin of the 650-kev level is $\frac{9}{2}$ and the parity is odd. The absence of positrons and arguments from log (ft) classifications indicate a spin of $\frac{9}{2}$ and even parity for the ground level of Sn^{113} and a decay energy in the range of 0.8 to 1.6 Mev. The shape of the corrected inner bremsstrahlung spectrum indicated a decay energy of 1.3±0.3 Mev.

* Supported by the Atomic Energy Commission.
† Now at Texas Technological College.
‡ Now at Davidson College.

M5. Decay of Cs^{134}. JOHN D. FRENCH* AND MAX GOODRICH, *Louisana State University.*—The gamma-ray in the decay of Cs^{134} (2.2 years half-life) have been studied with a scintillation spectrometer employing a cylindrical (3 in.×3 in.) crystal of NaI(Tl) and with a coincidence spectrometer using two such crystals in the spectrometers. The pulse spectrum in coincidence with the peak corresponding to each of the principal gamma-rays was obtained. The data indicate that at least fifteen gamma-rays are present, all of which occur in the nucleus Ba^{134} following negatron decay and none occur in the nucleus Xe^{134} following positron decay. Previously unreported crossover transitions of 1640 and 1970 kev, confirming levels at these energies, were observed. A decay scheme with energy levels in Ba^{134} at 605, 1038, 1168, 1367, 1401, 1640, and 1970 kev will be presented.

* Now at Alabama Polytechnic Institute.

M6. Beta-Gamma Angular Correlation in Eu^{152}.* HARRY DULANEY, L. D. WYLY, AND C. H. BRADEN, *Georgia Institute of Technology.*—Previous work[1,2] on the decay of Eu^{152} has indicated a unique shape for the 1460-kev beta group, an unusually large log *ft* product of 11.6, but a spin change of only one for the first forbidden beta decay. Preliminary measurements have been made on the beta-gamma angular

correlation between the 1460-kev beta group and the 345-kev gamma ray which follows the beta decay. Measurements at a beta energy of about 1100 kev yield a large negative anisotropy ratio of approximately 0.35.

* Supported in part by a grant from the National Science Foundation.
[1] Cork, Brice, Helmer, and Sarason, Phys. Rev. **107**, 1621 (1957).
[2] Abraham, Kedzie, and Jeffries, Phys. Rev. **108**, 58 (1957).

M7. Search for Angular Correlations Involving X-Rays.* HARRY DULANEY, J. L. REID, L. D. WYLY, AND C. H. BRADEN, *Georgia Institute of Technology*.—Standard scintillation counter coincidence techniques have been employed to search for possible angular correlations involving x-rays due to conversion or K capture. To date, no polarization sensitive detectors have been used and the various K series x-rays have not been distinguished. Our results, which are consistent with isotropic distributions in all cases, follow:

Nuclide	Radiations		Anisotropy ratio
Ce^{139}	(126 kev e^-)	(33 kev X)	-0.01 ± 0.02
Ce^{139}	(165 kev gamma)	(33 kev X)	-0.014 ± 0.010
Cs^{137}	(624 kev e^-)	(31 kev X)	-0.02 ± 0.02
Bi^{207}	(480 kev e^-)	(72 kev X)	-0.01 ± 0.03
Bi^{207}	(570 kev gamma)	(72 kev X)	0.01 ± 0.02
Bi^{207}	(976 kev e^-)	(72 kev X)	0.014 ± 0.013.

The (1060-kev gamma) (72-kev X) cascade in Bi^{207}, which presented a very unfavorable ratio of real to accidental coincidences, yielded a positive anisotropy ratio, Subsequent tests indicate that the positive result is probably due to interference in the measurement from the (570 gamma) (1060 gamma) cascade which is known to have a large positive anisotropy.

* Supported in part by a grant from the National Science Foundation.

M8. On Wiggles Estimates of Field Inhomogeneity. R. A. KROMHOUT, *Florida State University*.—In the measurement of chemical kinetics by nuclear magnetic resonance, the "wiggles" method of Jacobsohn and Wangsness is often used to measure the line width parameter "T_2" in cases where the line shape is determined by the field inhomogeneity. Although simple considerations lead one to expect a correlation between the line width and the wiggles decay time, the exact relation would be expected to depend on line shape. An exact solution has been obtained for the case of Gaussian line shapes, and some approximate relations have been worked out for other cases. Evidence is presented to show that the relationship characteristic of Lorentzian line shapes is semiquantitative at best, but fits much better than that expected for Gaussian lines.

Astronomy

(KENNETH M. YOSS presiding)

Invited Papers

N1. O Associations and Stellar Evolution. Part I. CARL K. SEYFERT, *Vanderbilt University*.
N2. O Associations and Stellar Evolution. Part II. DAVID CRAWFORD, *Vanderbilt University*.
N3. Space Astronomy. CARL HENIZE, *Smithsonian Astrophysical Observatory*.

Contributed Papers

N4. Relative Distributions of the Galaxies in the Coma Cluster. M. B. BAKER, *University of Florida*.—If the clusters of galaxies were in detailed equilibrium the time-scale of the universe would have to be of the order of 10^{18} to 10^{20} years. If the time-scale is of the order of 5×10^9 years, then there has not been enough time for a large interchange of momentum. A criterion for equilibrium is sought in the Coma cluster by comparing the counts of galaxies in the cluster to two different limiting magnitudes. Strip counts have been made on a 48-in. Schmidt plate and the counts have been compared in such a manner as to make the test independent of the background count and of the cluster size.

N5. Spectrophotometry of RS Ophiuchi, 1958. THEODORE P. STECHER AND ROBERT I. JOHNSON, *University of Michigan*, AND KENNETH M. YOSS, *Louisiana State University*.—The recurrent nova RS Ophiuchi had its third recorded outburst on July 14, 1958. It was observed with the Michigan instruments from July 17 through September 22. Twenty-eight spectra were obtained with the 37-inch reflector at five different dispersions, covering from 3100 A to 8800 A. The identified emissions include: H, HeI, HeII, FeI, FeII, [FeII], [FeX], NI, NII, NIII, OI, OIII, NaI, [AX]. The Curtis Schmidt telescope was used with the ten-degree objective prism combination to obtain forty-six plates with a total of sixty-five exposures, covering from 3600 A to 8800 A. Three early type stars of suitable magnitude range were recorded simultaneously with the nova. The plates were standardized by means of a spot sensitometer, while the comparison stars were also standardized against Vega with the photoelectric monochrometer. The spectra of the comparison stars and the nova from the Schmidt plates were traced on the microphotometer and transformed into direct intensity tracings. The monochromatic intensities for the comparison stars were then combined with the corresponding photoelectric measures to give a corrected characteristic curve. The brighter nova emission line intensities were then expressed in terms of the Code-Whitford monochromatic magnitudes for Vega.

N6. A Study of Line Profiles in the Spectrum of Procyon. LEON W. SCHROEDER, *Oklahoma State University* (introduced by Raymond T. Grenchik).—Recently Heiser[1] has reproduced the observed solar profiles of the magnesium triplet at 5175 A. The theoretical profiles were calculated on the IBM 650 electronic calculator using a model atmosphere, an assumed abundance for magnesium, and the necessary atomic parameters. The stratification of the model atmosphere was taken into account. In this paper investigation is made of the possibility of duplicating the "detailed" profiles by the simpler procedure of using Milne-Eddington pure absorption profiles with parameters determined at a particular depth in the same model atmosphere. An electronic calculator was used to facilitate making many trials with different parameters. The appropriate optical depth was found by trial and error to be 0.80. Two of the parameters can be obtained from the model atmosphere; the third from the observed central line in-

tensities. The results of the solar study were extended to the spectrum of Procyon where the same lines were duplicated using parameters from a Procyon model atmosphere.

[1] Heiser, Astrophys. J. 125, 470 (1957).

N7. Effects of Helium on a White Dwarf Atmosphere. RAYMOND GRENCHIK AND LAWRENCE NICOLA, *Louisiana State University.*—Since large amounts of helium are expected in the atmospheres of white dwarfs, a model atmosphere is calculated for 40 Eridani B assuming extremely high ratios of helium to hydrogen, i.e., 1, 10, 100, to see how this influences the emergent flux as compared to the flux from a helium free atmosphere. Using the Chandrasekhar grey body temperature distribution at a standard wavelength of 5000 A and the equation of mechanical equilibrium the model atmosphere is calculated with the aid of an IBM 650 computer. For four relative amounts of helium the temperature, pressure, fraction of unionized hydrogen, and the opacity are tabulated for optical depths ranging from 0 to 10. The ratio of the optical depth increment at any wavelength to the optical depth increment at 5000 A being proportional to the ratio of the absorption coefficients at these wavelengths, enables the calculation of corresponding optical depths at other wavelengths. The tabulation of these depths facilitates the calculation of the emergent flux. Thus the condition of constant flux for different depths is checked. Varying the amount of helium ultimately changes the electron pressure. Therefore a quantitative interpretation of hydrogen line profiles is possible by employing recent theories in line broadening

N8. Radio-Frequency Observations of the Planets in 1957–1958.* ALEX G. SMITH AND T. D. CARR, *University of Florida.*—Radio-frequency monitoring of several planets has been continued at 18 Mc/sec, 22.2 Mc/sec, and 27.6 Mc/sec. Observations of Jupiter over a period of 5 months during the 1957–1958 apparition have confirmed a rotational period of $9^h\ 55^m\ 28^s.8$ for the radio sources. Measurements of the polarization of the radiation indicate the existence of a Jovian magnetic field whose value has been estimated as 7 gauss by making several crude assumptions. Extended observations of Venus have failed to recover the previously announced spirodic radiation, and the results for Uranus have also been negative. Some indication of feeble radiation from Saturn has been obtained but the results cannot as yet be regarded as conclusive.

* This program is supported by the National Science Foundation, the U. S. Army Office of Ordnance Research, and the Office of Naval Research.

N9. Application of Television Techniques to Astronomy. JOHN H. DEWITT (introduced by Carl Seyfert), *A. J. Dyer Observatory, Vanderbilt University.*—The application of television techniques to astronomy has resulted in the development of a closed circuit system which has been successful in the photography of some of the major planets. Included in the equipment is an electronic image steadier which neutralizes some of the effects of atmospheric turbulence. With the development of the new Z5294 orthicon the possibility of reaching down to very low light levels has opened up. Stars of the 15th magnitude are presently being photographed in 8 sec at the cassegrain focus of the 24-in. reflector. It is anticipated that with slower sweep-off much lower intensity will be reached.

N10. Note on Possible Correlation Between Sunspots and West Indian Hurricanes. HARLAN T. STETSON (introduced by Paul Shearin).—Utilizing chronological data in Tannehill's authoritative volume on hurricanes, the occurrences of over 200 West Indian hurricanes showed little correspondence with sunspot numbers taking yearly values from 1750–1949. We have restricted solar data to the average of those months when hurricanes are most active. By so doing, the occurrence of West Indian hurricanes shows a tendency for an increase in hurricane activity as sunspots diminish in number. This tendency becomes emphasized if sunspot numbers are restricted into zones of solar latitude utilizing an average sunspot number for each zone width of thirty degrees. It appears that so far as the origin of West Indian hurricanes is concerned, the fewer the sunspots and the more distant from the solar equator, the greater the number of hurricanes. The years of maximum sunspot activity in the solar cycle (about 11 years duration) are likely to witness the fewest number of hurricanes during the hurricane season. An exhibition of this has occurred during the last three years of a record sunspot maximum.

MEETINGS AND DEADLINES THROUGH JUNE, 1960

Place	*Meeting dates*	*Deadline date*
Cleveland	November 27–28, 1959	September 25
Pasadena*	December 28–30, 1959	October 23
New York	January 27–30, 1960	November 13
Houston	March 4–5, 1960	to be decided
Detroit	March 21–24, 1960	to be decided
Washington	April 25–28, 1960	to be decided
Montreal	June 15–17, 1960	to be decided

* Abstracts for the Pasadena meeting are to be sent to W. A. NIERENBERG, University of California, Berkeley 4, California, and must reach his office not later than the corresponding deadline date. Abstracts for topical conferences are to be sent to the addresses given on page 380.

Abstracts for the other meetings listed above are to be sent to KARL K. DARROW, American Physical Society, Columbia University, New York 27, New York, and must reach his office not later than the corresponding deadline date. Take note that abstracts mailed the day before deadline day often fail to arrive in time: the last postal delivery of the day usually comes to our office before 2 P.M. Allow at least two days for abstracts sent by airmail from points east of the Mississippi, and longer for those sent from farther west. Abstracts postmarked (at the point of dispatch) on deadline day are instantly rejected, and telegrams heralding their arrival are fruitless except in revenue to the telegraph company. *The privilege of contributing papers to meetings of the American Physical Society is restricted to the members of the Society and to nonmembers whose papers are sponsored by members.*

DIVISIONAL MEETINGS (see pages 380, 381)

Place	*Subject*	*Meeting dates*	*Deadline date*
Ann Arbor	Fluid Dynamics	November 23–25	October 9
Monterey	Plasma Physics	December 3–5	to be decided

TOPICAL CONFERENCES (see page 380)

Los Alamos	Neutron Capture Reactions	October 1–3	August 7
Washington	Gaseous Electronics	October 14–16	August 29
Detroit	Magnetism and Magnetic Materials	November 16–20	to be decided
Gatlinburg	Reactions between Complex Nuclei	May 2–3, 1960	April 2

RULES AND INSTRUCTIONS FOR THE PREPARATION OF ABSTRACTS

The Council has ordered that abstracts shall be not longer than two hundred (200) words or the equivalent thereof. In reckoning equivalence, a footnote is equated to ten words; each line in a table to ten words; a "display" formula—one that requires a line to itself—is an expensive luxury equated to forty words.

Two copies of each abstract must be sent to the appropriate office. They must be typewritten; *one must be an original*, the other may be an original or a carbon copy. *Carbon copies will not be accepted in lieu of originals:* they smear. *Abstracts must be double-spaced:* single-spaced manuscripts are too crowded to permit the editorial markings to be made with ease and clearness. *Each abstract must be confined to a single page:* if it is too long for a single page it is too long to be printed. If we receive an abstract typed on two pages, we print only its first page. *Write each abstract as a single paragraph:* the suppression of paragraphs costs time and labor to the editors. *Do not use very thin paper:* a sheet of very thin paper may cause extraordinary trouble when mixed with sheets of reasonable thickness. The American Institute of Physics will bless you if you type first the title of your abstract in lower-case with capitalized initials, then your name in capitals, then the name of your institution in lower-case underlined with capitalized initials. It is a pleasure to report that those who qualify for this blessing are increasing in number but are still quite a bit short of 100% of the total. Issues of the *Bulletin* are always appreciably delayed because the editors have to do what the authors should have done.

Remember the rule of the Council that, if an author submits more than one abstract, all but one must go onto the Supplementary Program. In enforcing this rule, an abstract is credited to the author whose name appears first in the by-line.

It has now become an expensive business to make any change in an abstract, even the smallest, after the abstract has gone to press. By order of our Council "A change in an abstract will be permitted only at the discretion of the Secretary or his deputy, and only if TEN DOLLARS is enclosed with the letter in which the change is requested." As heretofore, an abstract will not be withdrawn from proof unless the asker sends ten dollars with his request.

Report of the Nominating Committee

The 1959 Nominating Committee of The American Physical Society has nominated to various offices of the Society, for terms beginning at the end of the 1960 Annual Meeting, the following candidates:

To the Presidency: V. F. WEISSKOPF
To the Vice-Presidency: FREDERICK SEITZ
To the Secretaryship: K. K. DARROW
To the Treasurership: S. L. QUIMBY
To the Managing Editorship: S. A. GOUDSMIT
To (two) posts on the Council: N. E. BRADBURY, D. W. KERST, P. KUSCH, L. R. MAXWELL.

To (six) posts on the Board of Editors, with special assignment to *The Physical Review:* T. H. BERLIN, S. D. DRELL, K. W. FORD, BENJAMIN LAX, LEONA MARSHALL, C. F. SQUIRE.

To (two) posts on the Board of Editors, with special assignment to *Reviews of Modern Physics:* M. DRESDEN, M. L. GOLDBERGER.

Of the foregoing, Messrs. Weisskopf, Seitz, Darrow, Quimby, and Goudsmit were nominated also by more than the requisite number of votes of the membership-at-large of the Society.